

Sky at Night
MAGAZINE

DISCOVER SPACE

BACK GARDEN ASTRONOMY

All you need to know to begin
your stargazing adventure



THE MOON ♦ THE PLANETS ♦ STARS ♦ CONSTELLATIONS
NEBULAE ♦ GALAXIES ♦ METEORS ♦ COMETS ♦ THE AURORA



CELESTRON®

TECHNOLOGICALLY SUPERIOR

THE NEXSTAR
EVOLUTION
KEEPS
EVOLVING

NexStar® EVOLUTION

8" EdgeHD with StarSense

Now paired together, enjoy the EdgeHD 8" optics and StarSense AutoAlign on the Evolution Mount. All controlled from your favourite iOS or Android phone or tablet with the new SkyPortal App.

Upgrade your NexStar Evolution for longer exposure astrophotography with the new Evolution equatorial wedge.

NexStar Evolution 8" EdgeHD
with StarSense AutoAlign

iPAD and iPHONE SHOWN
NOT INCLUDED.

NexStar Evolution 6" SCT

NexStar Evolution 9" SCT



Equatorial Wedge

Available from specialist astronomy retailers and selected other dealers nationwide.

Celestron is distributed in the UK & Ireland by David Hinds Limited. Trade enquiries welcomed.

www.celestron.uk.com

Celestron® and NexStar® are registered trademarks of Celestron Acquisition, LLC in the United States and in dozens of other countries around the world. All rights reserved. David Hinds Ltd is an authorised distributor and reseller of Celestron products. The iPhone® and iPad® are trademarks of Apple Inc., registered in the U.S. and other countries.



WELCOME



My first experience of truly dark skies came, as with most people, as a young child while on holiday. Every year my family would abandon our north London home to visit my nan in rural Dorset, where I was greeted by more green space than I knew what to do with, the delightful aroma of livestock and, once the Sun had set, absolutely stunning dark skies.

Of course, I had no real idea what I was looking at, other than a morass of stars. A wonderful, glittering morass, but a morass all the same. And so it is the case for so many. With so much to see, where do you begin?

In *Back Garden Astronomy*, we're aiming to make the night sky a little bit less bewildering. Within, you'll find everything you could possibly need to know for your first night under the stars and beyond. We start with essential knowledge, including why the sky moves, what the constellations are and why you need them, how we map the positions of the celestial bodies and what to look for in your first stargazing session. We move on to equipment next, explaining how to

“We’re aiming to make the night sky a little bit less bewildering”

choose a telescope, the value of binoculars and which accessories you might consider. Finally, we present the myriad delights that await – from the magnificent planets to meteors, comets, and the aurora.

This is the beginning of your astro adventure – and just so we're clear, you don't need to be in darkest Dorset to get started. There is plenty you can see in the sky from a suburban back garden.

That leaves one last thing to tell you, and that's the astronomer's equivalent of 'break a leg'. I wish you clear skies.

Kev Lochun
Editor

CREDITS

EDITORIAL

Editor Kev Lochun
Managing Editor Chris Bramley
Art Director Steve Marsh
Art Editor Rob Speed
Production Editor Ian Evenden

CONTRIBUTORS

Paul Abel, Ade Ashford, Will Gater, Pete Lawrence, Tom McEwan, Paul Money, Elizabeth Pearson, Steve Richards, Stephen Tonkin, Anton Vamplew

CIRCULATION / ADVERTISING

Head of Circulation Rob Brock
Advertising Managers
Neil Lloyd (0117 300 8276)
Tony Robinson (0117 314 8811)

PRODUCTION

Production Director Sarah Powell
Production Coordinator Emily Mounter
Reprographics Tony Hunt and Chris Sutch

PUBLISHING

Publisher Jemima Ransome
Managing Director Andy Marshall
Chairman Steven Alexander
Deputy Chairman Pete Phippen
CEO Tom Bureau

BBC WORLDWIDE, UK PUBLISHING

Director of Editorial Governance Nicholas Brett
Director of Consumer Products and Publishing
Andrew Moultrie
Head of UK Publishing Chris Kerwin
Publisher Mandy Thwaites
UK Publishing Coordinator Eva Abramik

uk.publishing@bbc.com

www.bbcworldwide.com/uk-anz/ukpublishing.aspx

© Immediate Media Company Bristol 2016. All rights reserved. No part of *Back Garden Astronomy* may be reproduced in any form or by any means either wholly or in part, without prior written permission of the publisher. Not to be resold, lent, hired out or otherwise disposed of by way of trade at more than the recommended retail price or in mutilated condition. Printed in the UK by William Gibbons Ltd. The publisher, editor and authors accept no responsibility in respect of any products, goods or services which may be advertised or referred to in this issue or for any errors, omissions, misstatements or mistakes in any such advertisements or references.

**IMMEDIATE
MEDIA^{CO}**

Like what you've read?
Email us at contactus@skyatnightmagazine.com

CONTENTS

UNDERSTANDING THE NIGHT SKY

- | | |
|---|---|
| <p>8 Stars, constellations and asterisms</p> <p>10 Star brightness and magnitudes</p> <p>12 Why the stars move</p> <p>14 The celestial sphere</p> <p>16 The ecliptic</p> <p>18 Star names and star charts</p> | <p>20 Your first night outside</p> <p>22 The secrets of star hopping</p> <p>24 Start stargazing the right way</p> <p>26 Seeing and transparency</p> <p>28 How to deal with light pollution</p> <p>30 Keeping a log book</p> |
|---|---|

32 SUBSCRIBE



WHAT TO USE EQUIPMENT AND ADVICE

- | | |
|---|---|
| <p>36 Introducing planispheres</p> <p>38 The value of binoculars</p> <p>40 Your first telescope</p> <p>44 Know your scope stats</p> <p>46 Know your field of view</p> <p>48 Know your telescope mounts</p> <p>50 Equatorial mounts</p> | <p>56 Go-to telescopes</p> <p>58 Choosing accessories</p> <p>60 Introduction to eyepieces</p> <p>62 Choosing eyepieces</p> <p>64 Understanding filters</p> <p>66 Astrophotography</p> |
|---|---|

WHAT TO SEE THE SOLAR SYSTEM

- | | |
|--|---|
| <p>70 The Moon</p> <p>74 Top 10 Moon sights</p> <p>76 Observing the Sun</p> <p>78 Solar and lunar eclipses</p> <p>80 Introduction to the planets</p> <p>82 The rocky planets</p> <p>84 The gas and ice giants</p> | <p>86 The moons of Jupiter and Saturn</p> <p>88 Meteors</p> <p>90 Comets</p> <p>92 The ISS and other satellites</p> <p>94 Noctilucent clouds</p> <p>96 Auroral displays</p> |
|--|---|

WHAT TO SEE DEEP-SKY OBJECTS

- | | |
|---|--|
| <p>100 The Milky Way</p> <p>102 The Messier catalogue</p> <p>104 Double stars</p> <p>106 Variable stars</p> | <p>108 Star clusters</p> <p>110 Nebulae</p> <p>112 Galaxies</p> |
|---|--|

114 INSTANT EXPERT: ASTRONOMY MYTHS DEBUNKED





110



CONTENTS

70



96



58



THE WRITERS

PAUL ABEL is an astronomer at the University of Leicester

ADE ASHFORD is an astronomer and science journalist

WILL GATER is an astronomy journalist, author and astrophotographer

PETE LAWRENCE is an astronomy expert and regular on *The Sky at Night*

TOM MCEWAN is a noctilucent cloud observer and founder of the NLC Observers' Homepage

PAUL MONEY is *BBC Sky at Night Magazine's* reviews editor and an equipment expert

ELIZABETH PEARSON is an astrophysicist and space journalist

STEVE RICHARDS is an astronomy equipment expert and a keen astro imager

STEPHEN TONKIN is a binocular astronomer and stargazing outreach expert

ANTON VAMPLEW is a seasoned observer and astronomy author

**SPECIAL
EDITION**

COMING SOON

FROM THE MAKERS OF



Sky at Night
MAGAZINE



YEARBOOK 2017

Explore the night sky over the next 12 months with *BBC Sky at Night Magazine's Yearbook 2017*. This indispensable astronomy bible contains a full year of stargazing tips, projects and how-to guides, plus amazing images and dates for all the astronomical

events you can't afford to miss. Each month of the year comes complete with its own detailed star chart to point you towards the best views.

Plus – subscribers to *BBC Sky at Night Magazine* receive FREE UK delivery on this special edition.

PRE-ORDER YOUR COPY TODAY

www.buysubscriptions.com/yearbook2017

Alternatively call 0844 844 0254† and quote 'SKYBHA17'

†Calls will cost 7p per minute plus your telephone company's access charge. Lines are open 8am-8pm weekdays & 9am-1pm Saturday.

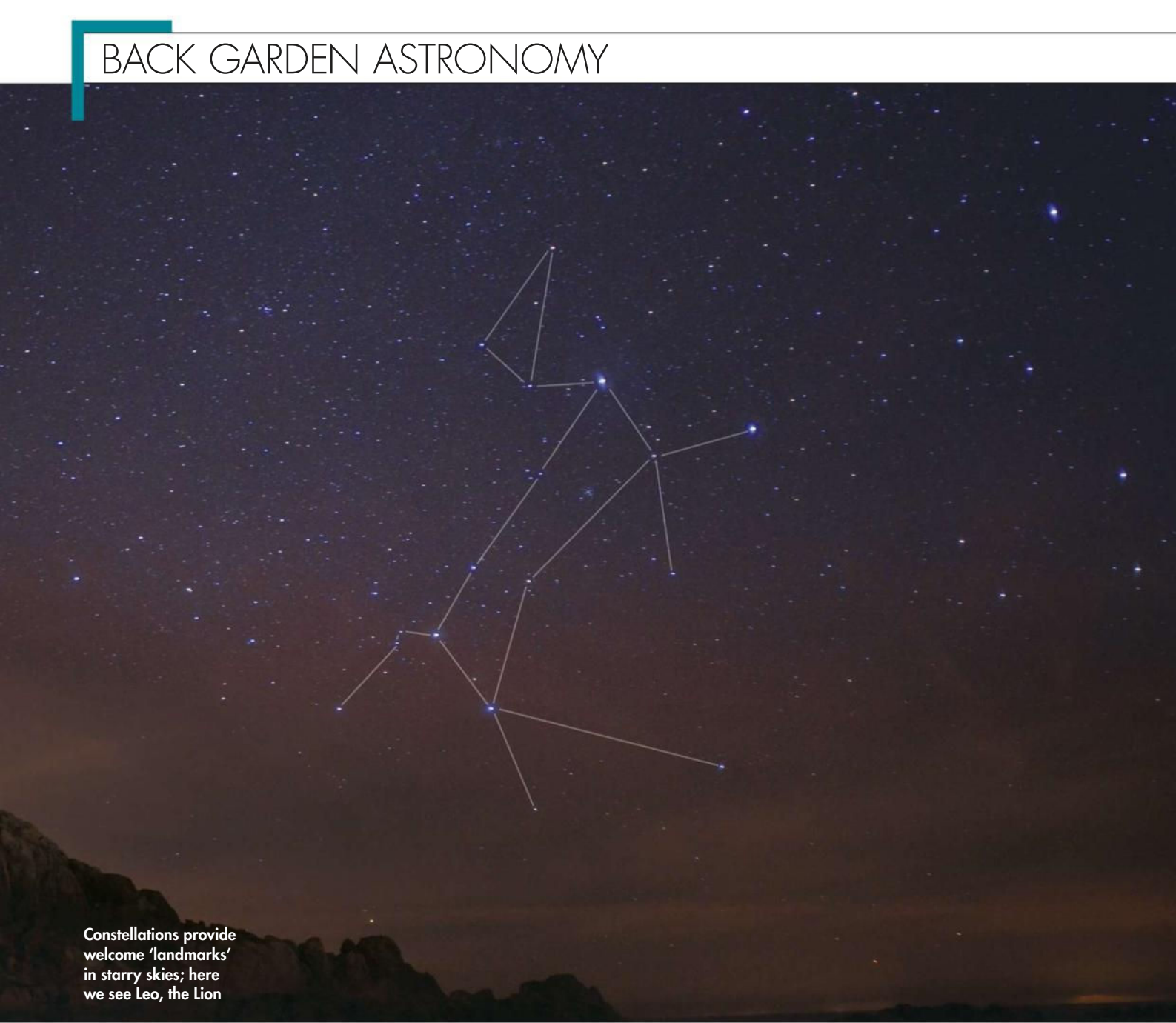
*Subscribers to *BBC Sky at Night Magazine* receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all other UK residents, £12.99 for Europe and £13.49 for Rest of World. Your copy will be dispatched when available from 30 November 2016.

UNDERSTANDING THE NIGHT SKY

The sky at night is magical, alluring and often bewildering – which is why our first section is all about helping you learn the basics. Starting with the stars themselves, we'll explain how these points of lights are categorised by your fellow astronomers, why they sometimes shimmer, and how to use the constellations they're organised into as signposts to find your way around and locate the denizens of the deep sky – clusters, nebulae and galaxies.

We also introduce a way of looking at the stars as a sphere around us with the Earth at the centre – very useful for mapping the night sky and for keeping track of things from night to night.

Once you have these fundamentals under your belt, you're guaranteed to get more out of stargazing. We've put together some practical advice on what you can do on your first night outside, top tips all beginners need to know, and how to deal with light pollution.



Constellations provide welcome 'landmarks' in starry skies; here we see Leo, the Lion

STARS, CONSTELLATIONS AND ASTERISMS

There are patterns in the skies that have been observed and mythologised for millennia

There are all sorts of celestial bodies to see in the night sky: the famous planets, wispy nebulae, far-flung galaxies and transient visitors such as comets and meteors. But it is best to start with the stars themselves.

At a glance they appear innumerable, and they may as well be. Under dark skies you can see a few thousand with the naked eye; peer through a pair of binoculars or a small telescope and

tens of thousands are within your reach. All of the individual stars that you can see exist within our Galaxy, the Milky Way, which is home to around 200 billion stars in all.

Stars are balls of hot plasma in which nuclear fusion reactions are taking place. The transformation of light elements into heavier ones, such as hydrogen into helium – and through successive cycles of reactions into carbon, nitrogen and

oxygen and on to iron – releases the energy that causes a star to shine.

Shining surprises

If you scan across the night sky you'll notice that the stars don't all shine with the same brightness, nor are they all the same colour, but a glittering array of rich golds, warm oranges, glinting sapphires and angry reds. The fact we see different colours is down to each star's surface

temperature: the hotter it is, the bluer the light it emits. They become more yellow in the middle of their lives and eventually red as they begin to exhaust their fuel and cool down. Stare long enough, and you will notice that the stars don't stay still, but appear to gradually move against the background sky. We'll find out why that's the case in a few pages' time.

The sky is split into zones called constellations, each of which is based on a pattern of stars that is said resemble an object, an animal or a figure from folklore or mythology. Some of these patterns are large and obvious, but others are much smaller, have fewer bright stars, and require a bit imagination to see what they are named after.

The stars that form the shape that gives each constellation its name are not necessarily related to each other – in fact many of them are vast distances apart, only appearing close in the sky from our perspective on Earth.

Constellation class

There are 88 recognised constellations in modern astronomy, and together they cover the entire sky. These aren't the only constellations that have ever existed – many more have faded into obscurity, been broken up or otherwise abandoned – but they are the only ones you need to know. Most people will be aware of at least 12 constellations, the ones that make up the astrological zodiac. (In astronomy there are 13 zodiacal constellations, the extra one being Ophiuchus).

Because the constellations span the entirety of the sky, by extension this means that every celestial object can be found within a constellation. For bodies beyond the Solar System, such as galaxies and nebulae, the constellation is 'fixed' – they will always appear to be in that one constellation. Bodies within the Solar System, such as the Moon and planets, appear to move across the constellations.

Particularly bright and easily identifiable star patterns are known as asterisms, and they can be comprised of stars within a single constellation or span several. For example, the Plough is entirely made up of stars within the constellation of Ursa Major, but the Summer Triangle comprises the brightest stars of Cygnus, Lyra and Aquila.

It's these brighter patterns that astronomers use as 'signposts' to help them identify other stars and find their way to the faint denizens of the deep sky.

STARTER STAR PATTERNS

Top constellations for amateurs learning the northern hemisphere sky



URSA MAJOR

Represents: The nymph Callisto, transformed into a large bear by Jupiter's jealous wife
Best visibility from UK: All year
Home to: The Plough asterism, easy to split double star Mizar and Alcor



ORION

Represents: Orion, son of Poseidon and the Gorgon Euryale. A gifted hunter
Best visibility from UK: December to March
Home to: The spectacular Orion Nebula and the Orion's Belt asterism



URSA MINOR

Represents: Arcas, son of Zeus and Callisto, turned into a small bear by jealous Hera
Best visibility from UK: All year
Home to: Polaris (the Pole Star)



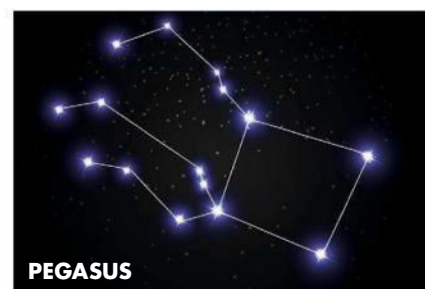
CASSIOPEIA

Represents: The queen Cassiopeia, mother to Andromeda, sent to the sky as a punishment
Best visibility from UK: All year
Home to: The W asterism



PERSEUS

Represents: The Greek hero Perseus
Best visibility from UK: August to April
Home to: Algol, the best beginner variable star; the radiant of the Perseid meteor shower



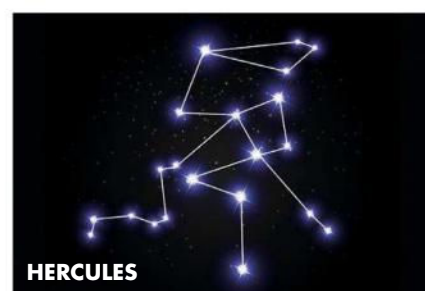
PEGASUS

Represents: A winged horse, offspring of Poseidon and Medusa, ridden by Bellerophon
Best visibility from UK: August to December
Home to: The Great Square asterism



ANDROMEDA

Represents: The princess Andromeda, chained to a rock to be eaten by Cetus
Best visibility from UK: August to December
Home to: M31, the Milky Way's 'big brother' galaxy, 2.5 million lightyears away



HERCULES

Represents: The Roman hero adapted from the Greek Heracles, with his club raised
Best visibility from UK: April to October
Home to: M13, the brightest globular cluster in the northern hemisphere

A quick glance of the sky will reveal that not all stars shine with the same brightness

STAR BRIGHTNESS AND MAGNITUDES

Knowing that not all stars are the same brightness will help you navigate the night sky

Occasionally the night sky just sparkles, and it's a terrific sight. After a rain shower, or something else, has cleared the air of all the dust, the stars look amazing.

Nights like these can be truly memorable, and reveal the full beauty and majesty of the Universe. Or rather, a small part of it. At such times we seem to see lots of stars, and the best ones stand out even more than usual. This effect can even happen in a built-up area where, thanks to the clearer air, the streetlights do not have so much to illuminate and so there is less light pollution.

One thing that is instantly apparent is that not all stars shine the same. There are a few that are very bright, some medium ones, and heaps of fainter stars that are more difficult to discern.

How bright a star looks is called its 'apparent visual magnitude'. You may see this written as 'apparent magnitude', 'visual magnitude' or just 'magnitude'. You may also see it abbreviated to 'mag.', as we do throughout this special edition.

What's strange about magnitude scales is that the numbering system is back to front – the brighter the star, the lower the number it is given. So a star of mag. +2.0

is therefore brighter than one that's mag. +5.0. Why the plus sign? Because there are stars brighter than zero – the scale extends into negative numbers.

To understand why, we have to cast our minds back more than 2,000 years and think about how the ancient Greeks tried to make sense of the heavens.

Astronomy Greek

If you could travel back to ancient Greece, the best person to seek out would be an astronomer and mathematician called Hipparchus. His initial thoughts about the night sky were probably the same as yours: it's immediately clear that not all of the stars and other astronomical objects are the same brightness.

Hipparchus called this variation in brightness 'magnitude', and based on this he catalogued the stars into six groups. He labelled the brightest stars as being of 'the first magnitude'. Slightly fainter stars he classed as second magnitude, and so on down to sixth magnitude. These are typically the faintest stars that can be seen with the naked eye alone.

The telescope hadn't been invented back then, so what the naked eye could

see was it. Nowadays, not only can we see much fainter celestial objects than Hipparchus could, but we have also been able to more accurately measure and refine Hipparchus's original magnitudes. The basic system that he invented remains intact, but the mixing of old and new has led to some interesting changes.

We now consider the mathematical difference between one magnitude and the next to be about 2.5 times in

WHY MAGNITUDES ARE USEFUL

Knowing the visual magnitude of a particular star, planet or deep-sky object can also give you some idea of what it's going to look like in the sky. For example, you can expect to find the mag. +7.5 Dumbbell Nebula in Vulpecula easily in a small telescope, but the dimmer mag. +10.6 Little Dumbbell Nebula in Perseus would be more of a challenge. There are many other things to consider, such as the object's size and the equipment being used, but visual magnitude is a good starting point.

brightness. What this means is that a first magnitude star is 100 times brighter than a sixth magnitude star. In the process, astronomers realised that some of the stars in Hipparchus's first magnitude group were wildly different in brightness, and so the scale had to be extended upwards into negative numbers. And so the brightest star in the night sky, Sirius in the constellation of Canis Major, is mag. -1.5 .

The bottom of the scale is now open-ended, growing as we find fainter and fainter stars – a 6-inch amateur scope can reveal objects as dim as mag. $+13.0$, while the Hubble Space Telescope has seen celestial bodies of mag. $+31.0$.

Hipparchus envisaged the magnitude system as a way of categorising stars, but today we apply it to all celestial bodies. The planet Venus can be as brilliant as mag. -4.5 , the full Moon mag. -12.7 and the Sun an intense mag. -26.8 .

Absolutely fabulous

So far we've been talking solely about apparent magnitude, which refers to how bright a star looks to us from Earth. It tells us nothing about how luminous an object truly is – its 'absolute magnitude'. Brightness decreases with distance, so a very luminous star a long way away may appear fainter than a dimmer star that sits closer to us. Consider Sirius: if it were the same distance from Earth as the Sun, it would appear brighter than our star.

To work out an object's absolute magnitude, we calculate how bright it would be if it were an arbitrary distance of 10 parsecs – 32.6 lightyears – away. By lining up celestial objects like this, we can 'see' how they differ from one another.

Hipparchus and his contemporaries knew nothing of these great distances. Just looking up at the sky, they are not readily apparent. Everything looks like it sits at the same distance from Earth. Absolute magnitude gives us some insight into the true nature of an object, but it has nothing to do with how it appears in a telescope. Happily, most star charts and observing guides list celestial objects in terms of apparent magnitude as standard.

THE FAINTEST STARS...

- Visible in a light-polluted sky: mag. $+3.0$
- Visible from a dark-sky site: mag. $+6.5$
- Visible with 10x50 binoculars: mag. $+9.5$
- Visible with a 6-inch scope: mag. $+13.0$

TOP TEN BRIGHTEST

The most brilliant bodies in the northern hemisphere's night sky



THE MOON

Magnitude: -12.7



VENUS

Magnitude: -4.5 (at its brightest)



MARS

Magnitude: -2.9 (at its brightest)



JUPITER

Magnitude: -2.8 (at its brightest)



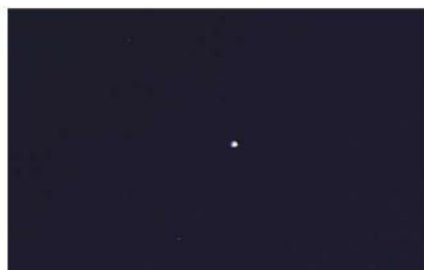
MERCURY

Magnitude: -1.9 (at its brightest)



SIRIUS (ALPHA CANIS MAJORIS)

Magnitude: -1.5



SATURN

Magnitude: -0.2 (at its brightest)



ARCTURUS (ALPHA BOÖTIS)

Magnitude: 0.0



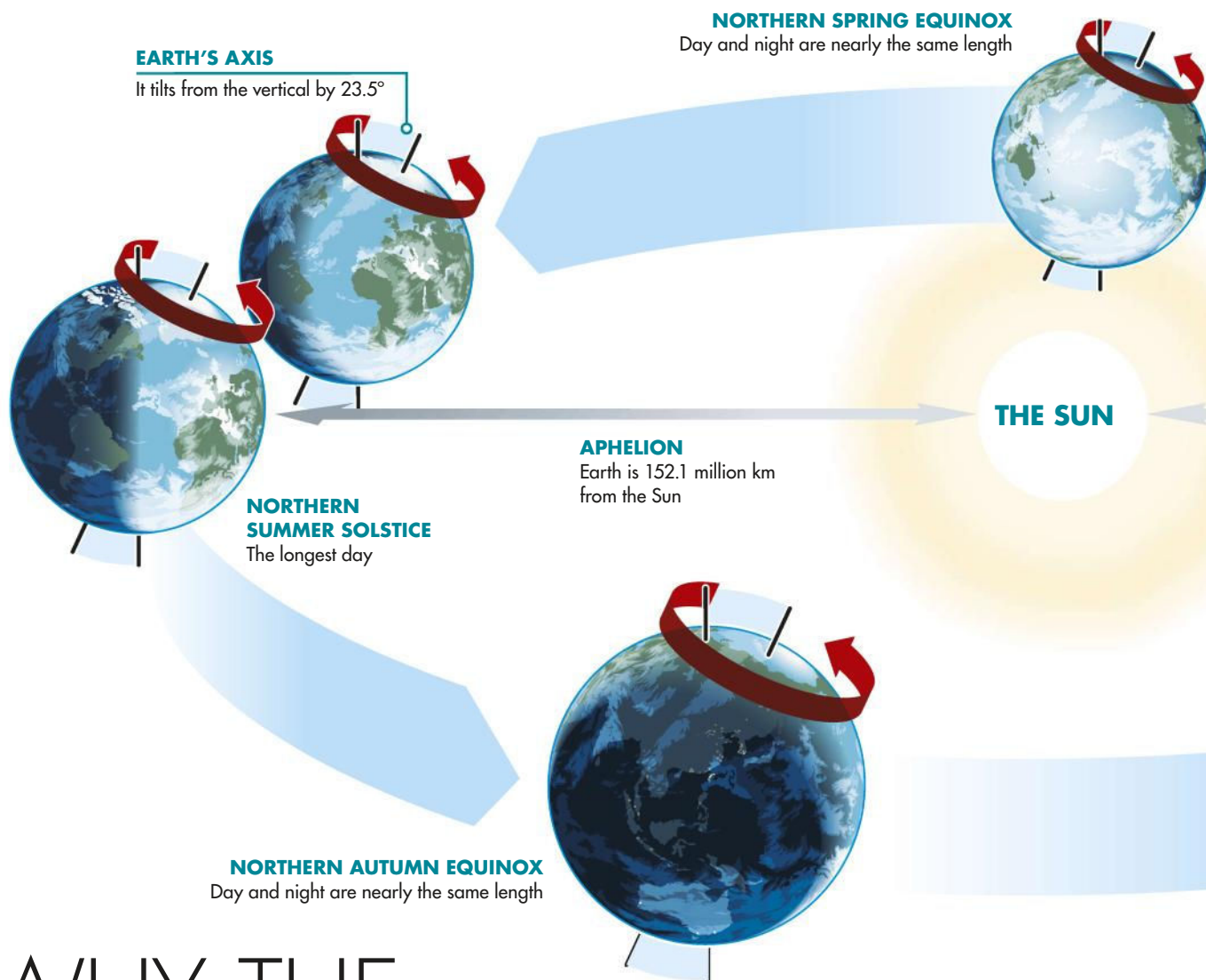
VEGA (ALPHA LYRAE)

Magnitude: 0.0



CAPELLA (ALPHA AURIGAE)

Magnitude: $+0.1$



WHY THE STARS MOVE

The movement of Earth makes the stars appear to march across the sky

We take it for granted that Earth is spinning and travels around the Sun. We have to, because there is no way any of us can feel the spin or the speed of our planet as it travels through space.

Cast your mind back to when you were seven years old. You're informed that the Sun crosses the sky because Earth turns on its axis once a day. And before you've had time to take this in you're told the Earth takes a year to go round the Sun.

A day in this context is the solar day, the time it takes our planet to complete

one rotation on its axis relative to the Sun, which lasts for 24 hours. A year is the time it takes for Earth to complete an orbit of the Sun. It is the fact that Earth is spinning on its axis that gives us the impression that the Sun and every other celestial object move across the sky.

Many people think that Earth experiences seasons because of its changing distance from the Sun. The distance between Earth and the Sun does change, as our planet's orbital path is slightly elliptical (like a squashed oval)

rather than circular, which leads to a difference of 5 million km between Earth's closest point to the Sun (perihelion), and its farthest (aphelion) – but you might be surprised to know that during northern hemisphere winter, Earth is as close to the Sun as it can get: perihelion happens around 3 January.

The seasons are due to Earth spinning on a tilted axis as it moves around the Sun, which varies the duration of sunlight hitting each hemisphere throughout the year. Model globes of Earth show this:

EARTH'S JOURNEY ROUND THE SUN

As it orbits the Sun, Earth spins on a tilted axis. Either the northern or southern hemisphere gets more direct sunlight, causing the seasons

PERIHELION

Earth is 147.1 million km from the Sun

NORTHERN WINTER SOLSTICE

The shortest day

A YEAR

Earth orbits the Sun in 365.26 days



DAY AND NIGHT

Earth spins on its axis once every 23.93 hours

15 DECEMBER, 7PM



15 JANUARY, 7PM



15 MARCH, 7PM



15 MAY, 7PM



Earth's motion through space causes the stars to rise earlier by four minutes every evening, with the long-term effect of causing the constellations to move over the course of the year

they lean by 23.5° from the vertical. You can see this lean in relation to our orbital path around the Sun in the diagram above.

Poles apart

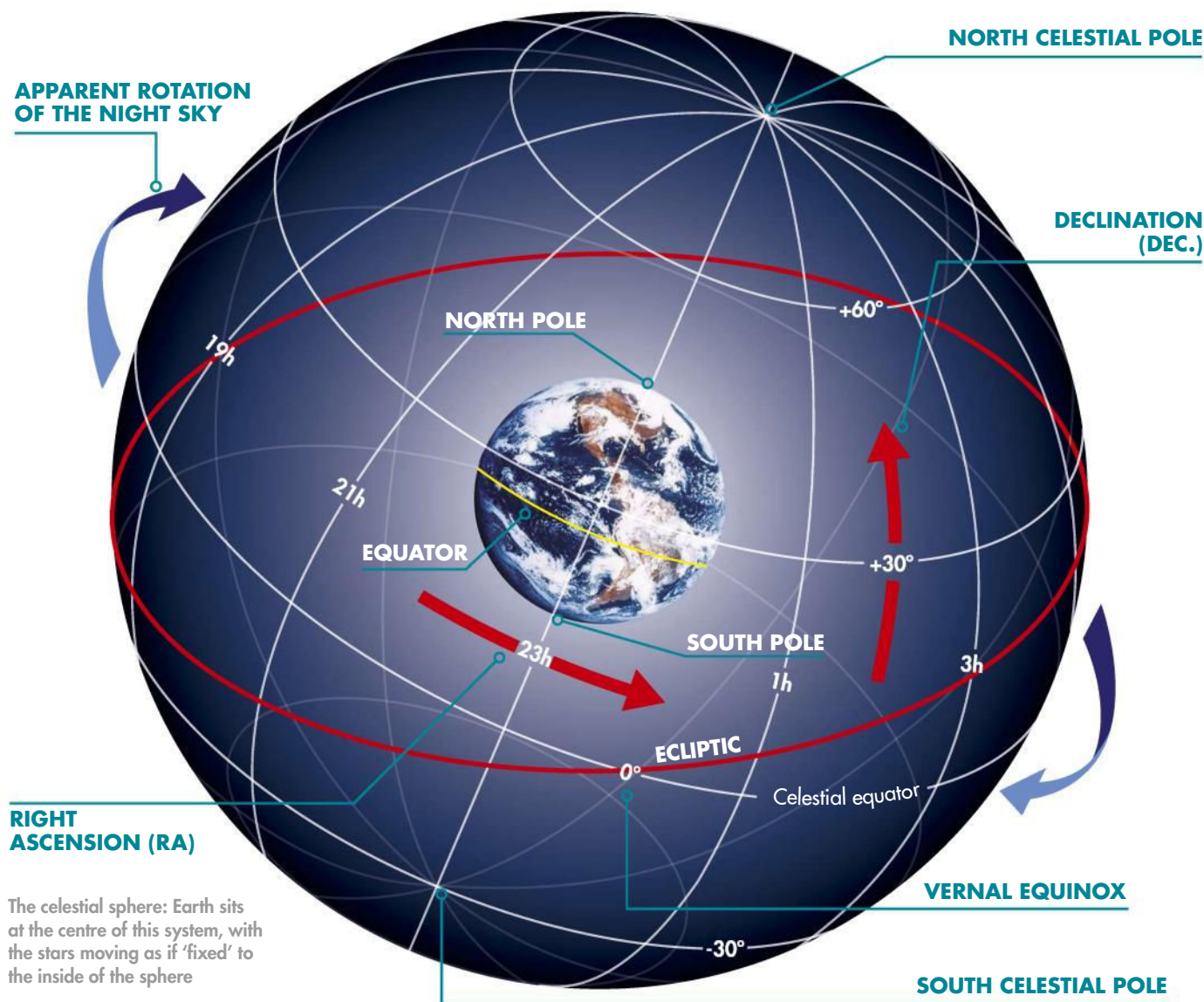
On the day that the north pole is tilted 23.5° towards the Sun, the south pole points away by the same inclination. For the northern hemisphere, the day this happens is the longest in terms of daylight hours (the summer solstice) and for the southern hemisphere it is the shortest (the winter solstice). Six months later, the tilt is reversed so that the south pole points towards the Sun and the

north pole leans away. This marks the shortest day in the northern hemisphere and the longest day in the southern hemisphere. As Earth goes round the Sun, its axis always tilts in the same direction in relation to the stars.

The Earth's motion doesn't just create the seasons. It also explains why our view of the constellations changes. We have covered how the solar day lasts for 24 hours, but Earth's rotation with respect to the stars is nearly four minutes shorter – it only takes 23 hours and 56 minutes for the stars to return to the same position that they were the night before, a period known as the

sidereal day. The reason for this discrepancy is that, from one day to the next, Earth completes $1/365$ th of its orbit around the Sun. So each night, if you were to look due east, you would be looking out onto a slightly different region of space.

This time difference between the solar and sidereal days, although short, causes the stars to rise almost four minutes earlier each day. Over the weeks and months, this causes the constellations visible in the night sky to change. After 12 months, the stars will have cycled all the way back to the same positions they were in a year ago.



THE CELESTIAL SPHERE

The imaginary lines that span the sky make locating a star as easy as reading a map

Individual stars are brain-defying distances apart in space, but you can forget all about that for now. It's all truly fascinating stuff and great for discussions with a cup of tea over the garden fence or to win a tricky pub quiz, but when you are out stargazing there is no practical benefit to knowing that Deneb in Cygnus

is over 70 times farther away from Earth than Vega in Lyra.

The fact is, celestial bodies are all so far away from us that for observing purposes we can consider them all to be the same distance. This applies as much to a distant galaxy billions of lightyears away as it does to the Moon at just a few

hundred thousand kilometres. Include man-made satellites and you bring the figure down to a few hundred kilometres.

What is the point of assuming everything's at one distance? It allows us to describe the position of a celestial object in relation to any of the others, as well as locate it in the sky. This is all done

by the power of an imaginary construct known as the 'celestial sphere'.

Consider Earth as a sphere with north and south poles. The celestial sphere is similar: a larger sphere, with Earth at its centre, and with north and south poles of its own. These poles, which we know as the north and south celestial poles, the NCP and SCP, are positioned above their Earthly counterparts.

If you were to stand on Earth's north pole and look directly upwards, you would be looking at the NCP, and the reverse applies to the SCP. By happy coincidence there is a mag. +2.0 star very close to the NCP; this star is Polaris, in the constellation of Ursa Minor, and it acts as a marker for the NCP from any location in the northern hemisphere.

Directly above Earth's equator lies the celestial equator, an imaginary circle that divides the celestial sphere. Observing the horizon from the poles would show stars located on the celestial equator. Observing from Earth's equator, the celestial equator would stretch from the eastern horizon to the western horizon in an arc directly over your head, and the celestial poles would lie at your northern and southern horizons.

Over the course of a year, observers at the equator will see the whole celestial

RA AND DEC. EXPLAINED

Every celestial object has celestial co-ordinates in right ascension (RA) and declination (dec.). For example, Deneb in Cygnus can be found at RA 20h 41m 25.9s, dec. +45° 16' 49".

In declination the ' symbol represents angular minutes (arcminutes) and the " represents angular seconds (arcseconds). A degree is a pretty large unit on the sky – two widths of the full Moon, in fact! So, 1° is divided into 60 arcminutes and each arcminute has 60 arcseconds. The + or – at the start shows whether it is in the northern hemisphere (+) or southern hemisphere (–).

Right ascension is written as hours, minutes and seconds (as in regular time, not the arc variety). So, one hour in RA describes the movement of the sky due to Earth's spin over an hour – which is 15°, because 15 multiplied by 24 (hours) is 360°, and that's all the way round over the course of a day.

Needless to say, star charts are all divided up so there's no need to convert anything – just plot the position and there will be Deneb.

WHY ASTRONOMERS NEED RA AND DEC.



Setting circles can help you to track down targets in lieu of a Go-To mount

Many popular targets are small or dim, making them difficult to locate through the eyepiece even with star hopping. Using RA and dec. co-ordinates allows us to easily locate these more elusive objects. The co-ordinates for a given target can usually be found from various sources: star

charts, online via a web search, or through planetarium programs and apps. If you have a Go-To mount, it will be able to calculate the position of any objects in its database and automatically point to the correct place in the sky. However, you can also use the setting circles on many

manual equatorial mounts. Start by locating a bright star close to your target; dial in its co-ordinates carefully and check its position. Move the scope in RA and dec. until they match the co-ordinates of your target; it should now be visible in a low-magnification eyepiece.

sphere, whereas those at the poles only ever see their respective half of the sphere. At any point between the poles and the equator, you would see some stars from both halves.

There is a second important line on the celestial sphere you need to be aware of, called the ecliptic, and it represents the path of the Sun through the year. We discuss why it is so important over the page. Because Earth's axis is tilted at an angle of 23.5° with respect to its orbit around the Sun, the ecliptic too is tilted at the same angle with respect to the celestial equator.

Total ecliptic

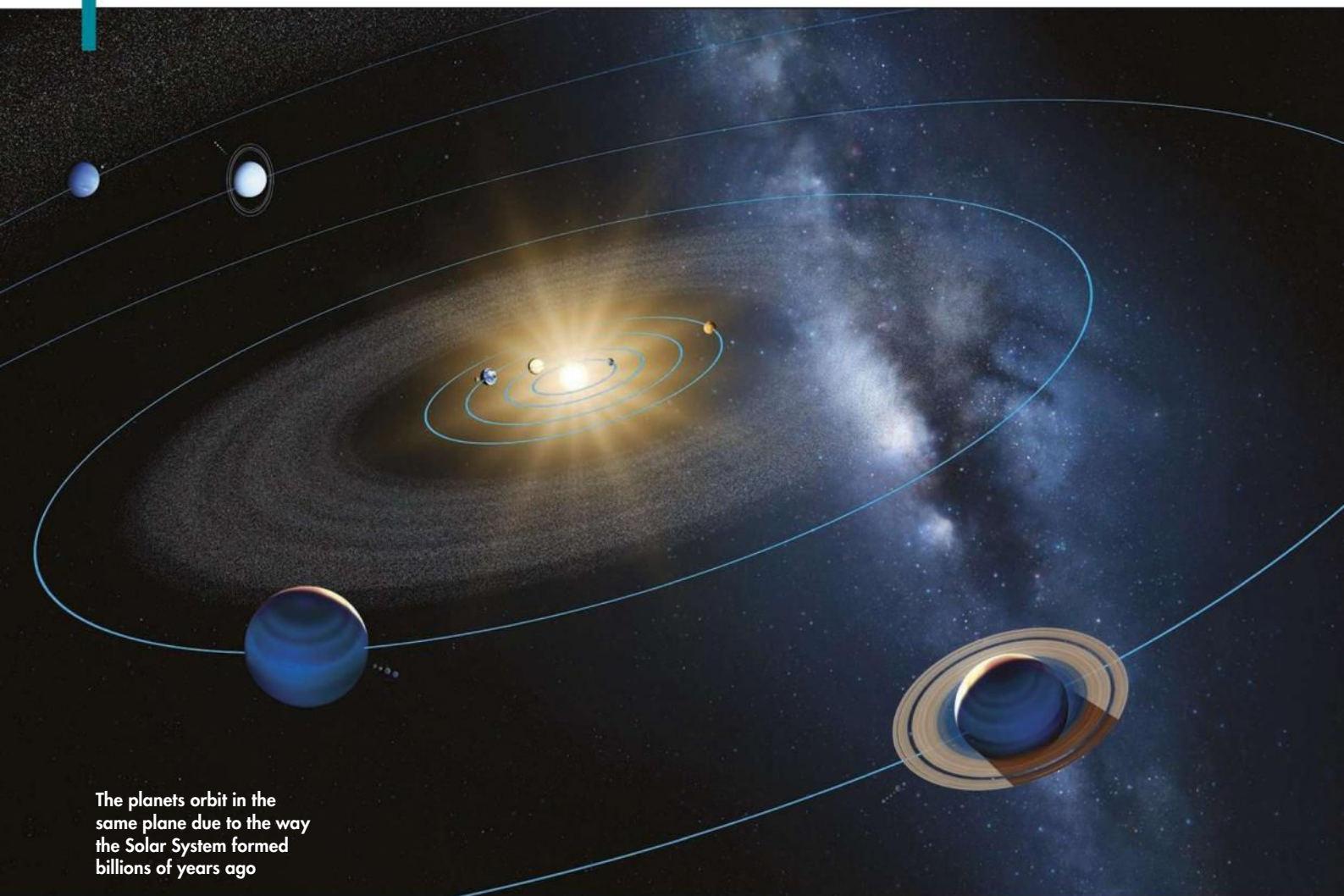
Mapping on the celestial sphere works much like mapping on Earth. As you'll remember from geography lessons at school, to locate something down here we use latitude and longitude. The equator is the most famous line of latitude and is the starting point for measuring northward or southward – we call this 0° latitude. We use degrees (°) because when we locate places on Earth, or on the celestial sphere, it's done using angular measurements. Latitude increases as we move round Earth northwards or southwards, reaching a maximum of 90°N at the north pole and 90°S at the south pole.

Lines of longitude, meanwhile, start from the north pole and run 'down'

Earth, crossing the equator and ending at the south pole. These locate things east to west on the plane and are also measured in degrees. Here, of course, longitude crosses all the points around the equator (a circle), amounting to 360° in total. Actually, we move westward up to 180° and eastward 180°, but it all adds up to 360° in the end.

For the celestial sphere, we throw the whole latitude and longitude Earth grid up into the sky – it's a mirror image. There's no reason why we couldn't have used celestial latitude and celestial longitude as titles, but those who know better decided otherwise. So instead we have 'declination' for latitude and 'right ascension' for longitude. We can describe the position of any object in the night sky using these co-ordinates.

Declination is how far an object is located above or below the celestial equator, and is measured in degrees (°), arcminutes (') and arcseconds ("). Right ascension is an angular measurement in hours (h), minutes (m) and seconds (s) eastwards from a point on the celestial sphere known as the vernal equinox, which forms the zero point for the entire grid. This is the location of the Sun on the celestial sphere at the point that it crosses the celestial equator at the March equinox – the date in March when day and night are nearly equal in length.



The planets orbit in the same plane due to the way the Solar System formed billions of years ago

THE ECLIPTIC

The path of the Sun, where you'll find the rest of the Solar System's planets, is the second of two important lines that astronomers use to divide up the night sky

Up until the early 1600s, the idea that the Sun orbited the Earth was perfectly acceptable to a lot of people. The reason our ancestors believed in this geocentric (Earth-centred) model was, of course, because that's what we see happening in the sky. Or so it appears.

From our planet, it looks as though the Sun moves around us over the course of a year. As we now know, this isn't really the case – in truth our planet orbits the Sun, as do all the other planets in the Solar System. But this illusion forms one of the most important markers on the sky, the line we call the ecliptic.

The ecliptic is the invisible path that the Sun traces as it moves around the sky. Think of it like this: if the Sun were to drop breadcrumbs behind it like a

cosmic Hansel and Gretel, this is the trail it would leave behind. The Sun can always be found on the ecliptic – it never deviates from it. But it also represents something else: the orbital plane of our planet.

Disc formation

All of the planets in the Solar System occupy orbital planes similar to our own. This is because when the Solar System formed, billions of years ago, dust and

gas surrounding our nascent star was pulled into a disc under the influence of gravity. The planets we know today all formed within this disc, and hence they all occupy planes similar to the ecliptic. In plain terms, when the planets are visible, they will always be near to this line.

It's this 'coplanar' nature of the Sun and planets that allows many of the events that captivate astronomers to occur so often. When our Moon and

“The planets all formed within a disc, and hence they all occupy planes similar to the ecliptic”

the Sun line up, we see an eclipse. When a planet appears to be in the same region of sky as another, or our own Moon, we call it a conjunction. Even seemingly rare events, such as a transit of Venus, are really quite frequent in cosmological terms.

Equal nights

The two points at which the ecliptic crosses the celestial equator mark the moments when the hours of day and night are roughly the same. These are known as equinoxes, from the Latin for 'equal night'. In the northern hemisphere, the equinox in mid-March heralds spring, while the one in mid-September signals the beginning of autumn. At these two points in its orbit, Earth has no tilt relative to the Sun.

From the March equinox, the days slowly lengthen until mid-June, when Earth reaches the point in its orbit where it is at its greatest tilt relative to the Sun – a solstice. This is both the first day of summer and the longest day of the year. At this point, the ecliptic and the celestial equator are at their farthest apart.

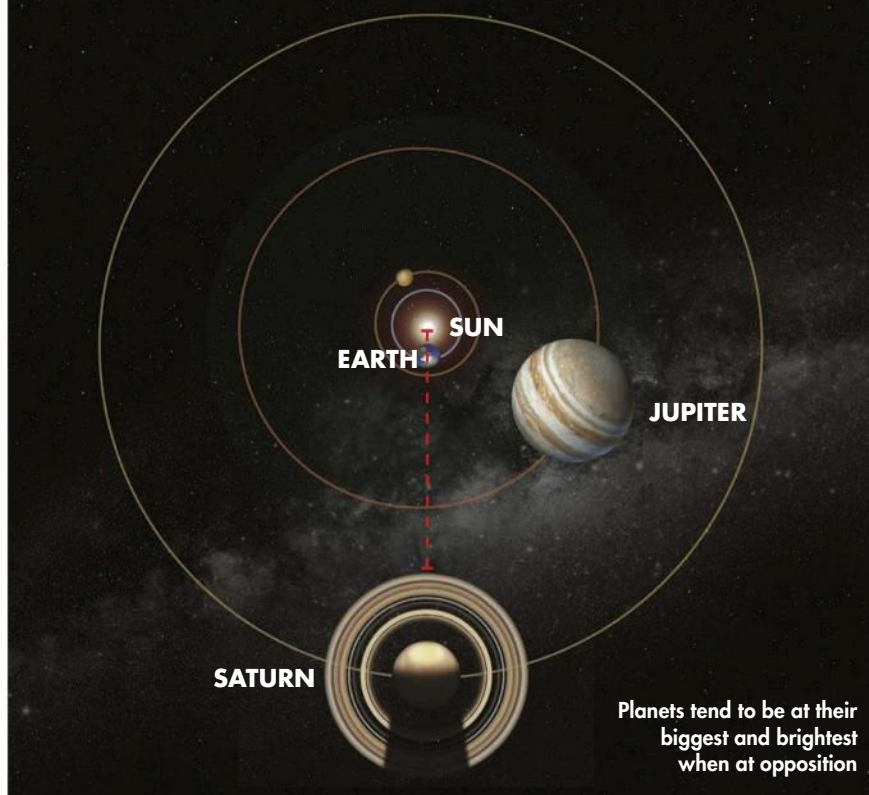
There's another solstice six months later in mid-December, when the tilt of the poles is completely reversed in relation to the Sun. In the northern hemisphere, this marks the start of winter and is also the shortest day.

PLANET OPPOSITIONS

Oppositions, another result of the Solar System being coplanar, occur when the Sun, Earth and another planet form a line, with Earth in the middle. From our perspective, the planet is in the opposite position in the sky from our star. As such, only the superior planets – those with

orbits farther out from the Sun than Earth's – reach opposition.

A planet at opposition is usually at its closest to Earth, and therefore appears larger than at any other time. Due to its position relative to the Sun, a planet can be brighter than usual too.

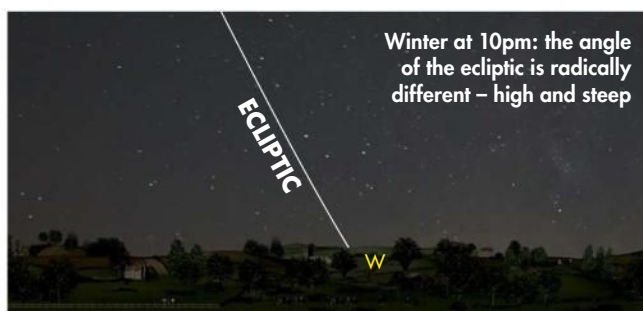
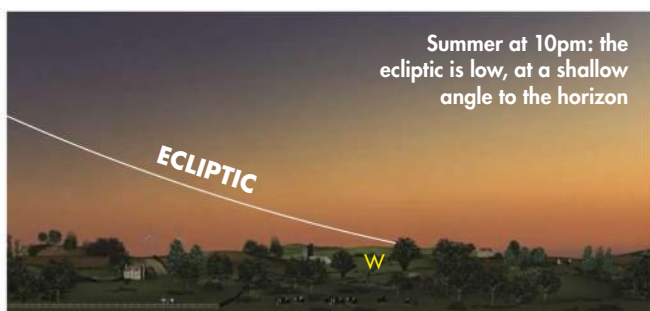


THE SHIFTING ECLIPTIC

The Sun always sits on the ecliptic, so it's easy to work out where the line is on any clear day. Looking at the whole year, we know that the

Sun – and hence the ecliptic – is higher in the sky through the day in the summer months and lower during the winter. But what about at

night? If you can work out where the ecliptic traces across the sky after darkness falls, you can work out where you might spot a planet.



SPRING

The ecliptic sits low down in the morning, but in the evening it stretches high across the sky from east to west, making the dusk skies the best time to see Mercury and Venus, as they never stray far from the Sun.

SUMMER

In summer the ecliptic sits at a low elevation by dusk, so any planets are mired in the atmospheric murk. The ecliptic's orientation swings from northwest-southeast in the evening to northeast-southwest in the morning.

AUTUMN

In a reflection of the northern hemisphere spring, the ecliptic's evening path is now low down, but in the morning it stretches high across the sky from east to west. This makes the dawn skies the best time to see Mercury and Venus.

WINTER

The ecliptic path in winter is quite high when it's dark, and moves higher until it reaches maximum elevation at midnight. This is a great time for observing planets, as you're able to look at them though less atmosphere.

STAR NAMES AND STAR CHARTS

Learning how astronomers name stars is critical to finding your way around the sky

Of the thousands of stars visible from planet Earth, only a few hundred have been given proper names, mostly by the astronomers of antiquity. Many of these are based on corruptions of Arabic phrases that describe their place within a constellation – for example, Algol in Perseus is derived from ‘Ra’s al Ghul’, an expression meaning ‘head of the demon’. It represents the eye of the Gorgon Medusa being held aloft by Perseus. Some have been named entirely on their own merits, such as Sirius, the brightest star in the heavens, which is derived from an Ancient Greek word meaning ‘scorcher’.

Most of the information we have about the Greeks’ thinking and constellation designs comes from a giant multi-volume work, *The Almagest* (also known as *The Great Syntaxis Of Astronomy*), by the mathematician and astronomer Ptolemy around 150 AD. Well over a thousand years later, this ‘book’ found its way to Italy and was translated into Latin, which is why we have Latin names for the constellations that endure today.

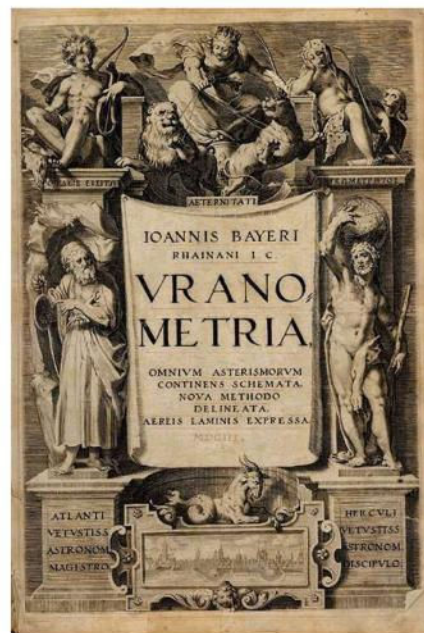
Up until the dawn of the 17th century these were the only widely accepted stellar designations we had, but German

astronomer Johann Bayer changed that in 1603 with the publication of his star atlas, *Uranometria*. In homage to earlier astronomers, he labelled the brightest stars of a constellation with Greek letters – usually alpha for the brightest, then beta, gamma, all the way to omega. So Sirius in Canis Major, the constellation of the Great Dog, also became known as Alpha (α) Canis Majoris. When the Greek letters ran out, he used Latin letters.

A sense of belonging

You’ll notice that the constellation’s name is spelt differently when being used to describe a star. This is the genitive form of the constellation’s name, meaning ‘belonging to’. All constellations have this Latin possessive, such as Geminorum for ‘belonging to Gemini’. They also have three-letter abbreviations: Canis Major’s is CMa, so you might see Sirius referred to as ‘α CMa’.

We say that the alpha star is ‘usually’ the brightest because there are a handful of instances where Bayer either got it wrong or decided to apply a different convention. In Orion, for example, Rigel is brighter than Betelgeuse, but Betelgeuse is the alpha star, ostensibly because Bayer recognised they were



Bayer's *Uranometria* uses star position data more accurate than Ptolemy had access to

of similar brightness and simply named Betelgeuse as the alpha star because it rises first.

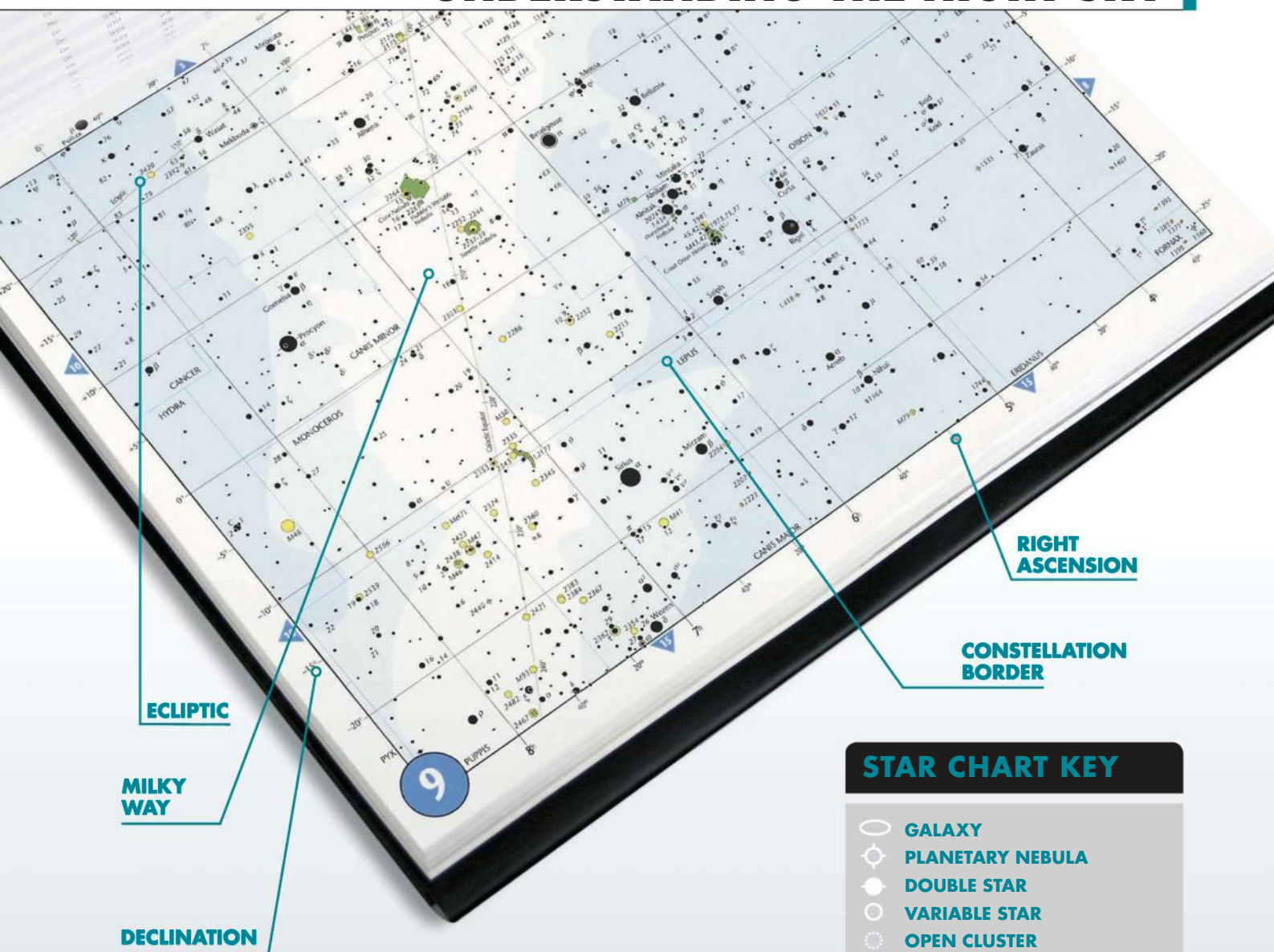
Bayer's is not the only stellar catalogue – in fact almost every star in the night sky is part of one catalogue or another – but it is the most widely referenced. Of the

IT'S ALL GREEK TO US

It's well worth getting to know the Greek alphabet, rather than thinking of Bayer designations as Egg, Fish, and That One I Remember From Maths Lessons

α	β	γ	δ	ε	ζ	η	θ	ι	κ	λ	μ
Alpha	Beta	Gamma	Delta	Epsilon	Zeta	Eta	Theta	Iota	Kappa	Lambda	Mu
ν	ξ	ο	π	ρ	σ	τ	υ	φ	χ	ψ	ω
Nu	Xi	Omicron	Pi	Rho	Sigma	Tau	Upsilon	Phi	Chi	Psi	Omega

UNDERSTANDING THE NIGHT SKY



STAR CHART KEY

- GALAXY
- PLANETARY NEBULA
- DOUBLE STAR
- VARIABLE STAR
- OPEN CLUSTER
- GLOBULAR CLUSTER

myriad other star catalogues, perhaps the most useful is John Flamsteed's, which organises stars by constellation and designates them with a number. In this scheme, Sirius is 9 Canis Majoris.

Chart to chart

That's how stars are named, but how do you translate this knowledge onto the night sky? The answer is to consult a star chart. Stars are most commonly marked by their Bayer designations or, if they lack a Bayer letter, their Flamsteed number.

One thing that you'll immediately notice is that the brighter stars are

shown by the biggest dots. Although all stars are points of light in the real night sky, it is impossible to show their brightness any other way on a printed page. If your chart happens to be circular – as is the case with the monthly all-sky charts often found in astronomy magazines – be aware that the constellations will appear warped at the edges. When a 3D sky dome is flattened, the sky at the horizon gets stretched, which means the star patterns will not match those in the sky.

But there's more to atlases than just star positions and brightness – although

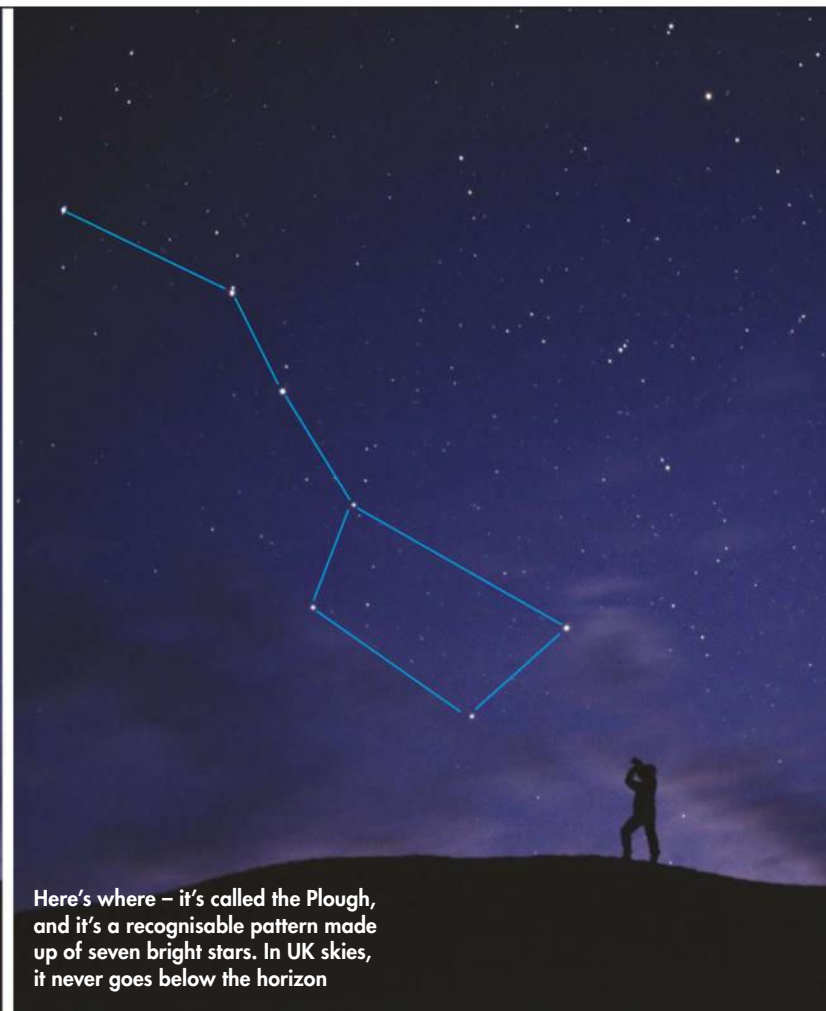
they are, of course, vitally important if you're trying to learn the sky. With symbols that don't detract from the overall view, you can identify stars that are variable in brightness or appear together with another star, forming a 'double star'. Depending on your atlas there may also be additional symbols for deep-sky objects such as nebulae, globular clusters and galaxies.

A useful atlas should have charts that vary in detail. You may, for example, have general seasonal charts or monthly charts, close-ups of some constellations and possibly a location chart for some of the deep-sky objects. It may also display the ecliptic and celestial equator, as well as the coordinate lines of right ascension and declination. As a beginner it's probably the seasonal or monthly charts that you'll use the most, so make sure you're happy with the style.

“Bayer labelled the brightest stars of a constellation with Greek letters – usually alpha for the brightest”



So, you've found a nice dark spot in the northern hemisphere for your first night of stargazing, but where do you begin?



Here's where – it's called the Plough, and it's a recognisable pattern made up of seven bright stars. In UK skies, it never goes below the horizon

YOUR FIRST NIGHT OUTSIDE

Begin your astronomical adventure by learning your way around the Plough asterism and using it to find the pole star

Standing under a starry sky, awash with pinpricks of light, can as bewildering as it is mesmerising. So, once you have a clear night, where do you begin? Assuming you live in the northern hemisphere at a mid-to-high latitude – which do if you live in the UK – your first goal is to find the group of seven stars known as the Plough. The Plough is an asterism within the constellation of Ursa Major, the Great Bear; an asterism being a bright and recognisable pattern of stars often (but not always) from a single constellation. This one happens to look like a saucepan, and it marks the bear's tail and back.

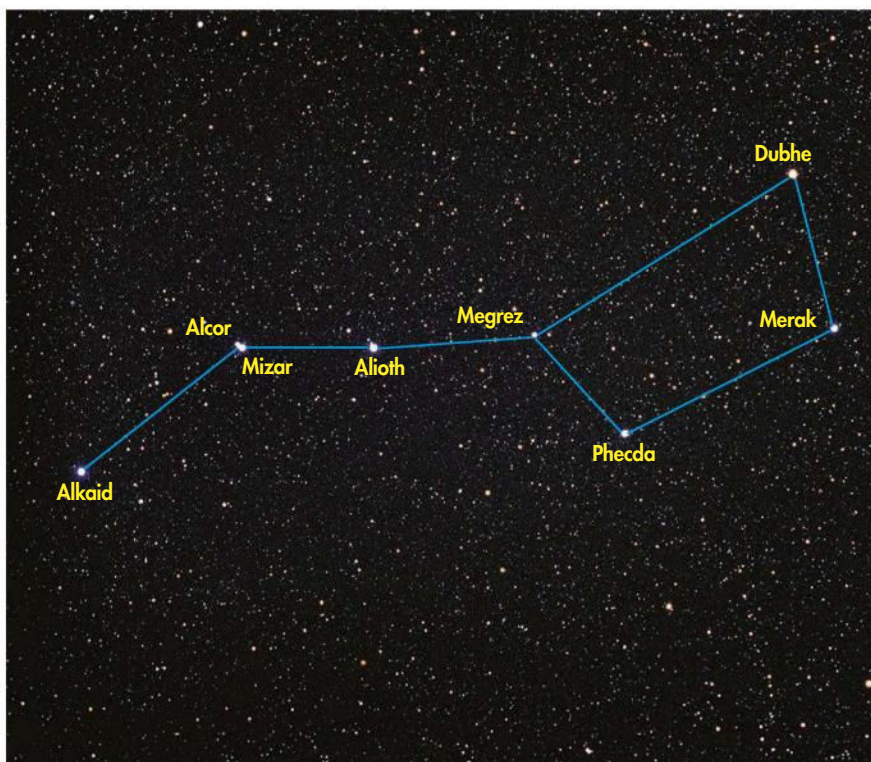
The reason we're starting here is not only because the Plough is bright and

easy to find, but because we have to take into account the rotation of the Earth. Just as the Sun rises, moves over the sky and sets, so many of the stars do the same thing at night – though not all. From UK latitudes some stars remain above the horizon all night long, including those in the Plough. As the Earth itself moves around the Sun we also see a slight shifting of stars night-by-

night, which means some constellations enter and leave our skies over the course of a year. Again, the Plough is a constant presence, visible throughout the year. Combined, this means it is a handy pattern to learn, and a good place from which to launch your stargazing quest and get to know the starry skies.

The Plough can be found in the northern sky. To locate it, you need to

“Just as the Sun rises, moves over the sky and sets, so many of the stars do the same thing at night”



Get to know the stars that make up the Plough: Alkaid, the Alcor-Mizar double, Alioth, Megrez, Phecda, Dubhe and Merak. In case you're wondering, these stars all owe their names to medieval Arabic astronomers. American sources may refer to it as the Big Dipper



A long-exposure photograph centred on Polaris will show the way the heavens rotate

know which direction north is. You could use the Sun to guide you: north will be to the left where the Sun rises, or to the right of where the Sun sets. The highest the Sun gets in any day is due south, so of course north is opposite to this. Alternatively, you can use a compass.

Name that star

It's worth noting that each of the Plough's seven stars has a name; not all stars do. We're going to start with the star at the crook of the Plough's handle, which is called Mizar. It has a companion that's not quite as bright, and together they form a well-known double star that is visible to the naked eye. Look above and left of Mizar at a distance of about one-third of the diameter of the Moon, and you should be able to spot the companion, Alcor. This is the first of many double stars waiting for you.

Both Mizar and Alcor are white stars, but on the other side of the Plough you'll find your first coloured star. The top-right star of the Plough's bowl has a slight orangey-yellow hue. This star is called Dubhe, and it is the brightest star in the asterism. The best way of seeing its orangey-yellow hue is to compare it with the star below it in the Plough: the pure white Merak. If you flip your gaze between the two, the orangey-yellow colour of Dubhe should become readily apparent.

Now that you know where Dubhe and Merak are, you've discovered two of the most useful stars in the night sky. These two stars are known as the Pointers, because they can make it easy to locate the Pole Star, which astronomers know by the name Polaris. We'll do this using a technique that has been tried and tested over thousands of years, known as star hopping.

Starting at Merak, draw an imaginary line through Dubhe and keep going. The next star of any note you come across is Polaris. Don't expect this to be a super-bright example of stellar marvellousness – it isn't. Polaris is just an ordinary-looking star. It's famous because it sits almost directly above Earth's north pole and so appears to stay practically in the same place as our planet spins, with the rest of the night sky rotating around it.

This is just the start. In the Plough, you have a launch pad from which you can explore many more stars and constellations.

THE SECRETS OF STAR HOPPING

You don't need to completely memorise the night sky to find things to look at; instead, you can jump from one star to another

For those new to astronomy, staring into the clear night sky and seeing hundreds of points of light can lead to a common conundrum: how will I ever find my way around this bewildering confusion of stars?

One way is to buy a telescope with a mount that can take you to any object in its database at the press of a button. But there is a much simpler alternative, tried and tested over thousands of years, which experienced observers still use to find objects we cannot see with the naked eye. We call it star hopping.

The brighter stars form recognisable patterns – constellations, asterisms, and even simple geometric shapes – and we can use those patterns as ‘jumping off

points to less obvious and fainter regions or objects of interest.

The key to star hopping is accurately estimating directions and distances. For directions, use pairs of bright stars that approximately align to your target, imagine a line between them and follow it to your destination. Alternatively, if you know the angular distance your target is from another star (how far away it is in degrees), you can use your hands to estimate those distances. Stretched out at arms length, your hand is a rudimentary angle measurer, offering easy approximations of angles ranging from 1° to 25°.

When you transfer these skills to binoculars or telescope finders, make sure you know the angular diameter of

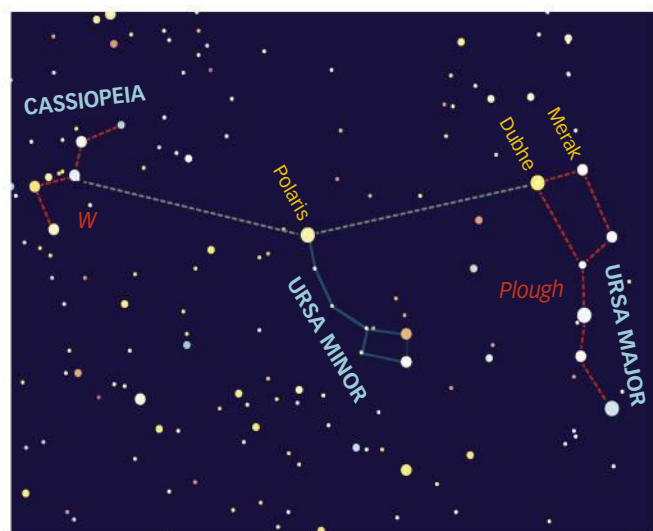
the field of view, as you can use this to estimate angular distances.

Surprising size

One thing you will need to practice is relating the scale of your star chart to the scale of the sky. Find a constellation or asterism in the sky and then locate the same group on your chart: you will probably be surprised at how much bigger it looks in the sky! Now look for other prominent groups of stars on your chart and locate them in the sky, trying to keep the relative scales in mind. Reverse and repeat. Take your time with this: you are building a firm foundation that will serve you well for the rest of your observing career. Here are a few to get you started.

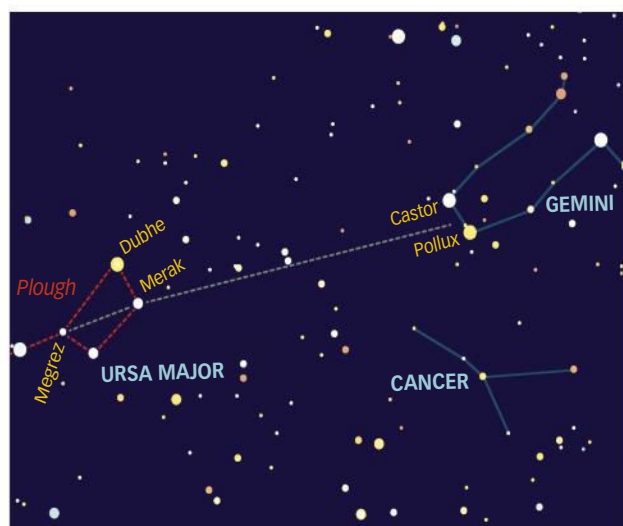
SIGNPOSTS IN THE STARS

The Plough is a useful asterism to know. Here are four celestial regions it can point you towards



THE W OF CASSIOPEIA

You've already seen how to locate Polaris. Now continue this imaginary line onwards for the same distance that you've already come from the Plough, take a slight bend to the right, and you arrive at the constellation of Cassiopeia (the Queen), which appears in the form of a W of stars.



CASTOR AND POLLUX IN GEMINI

To get to Castor and nearby Pollux, the main stars of Gemini (the Twins) start from the Plough star Megrez. Draw an imaginary line to Merak, diagonally opposite it, and keep going. Almost halfway to your target you'll pass the two stars that form the front paws of Ursa Major.

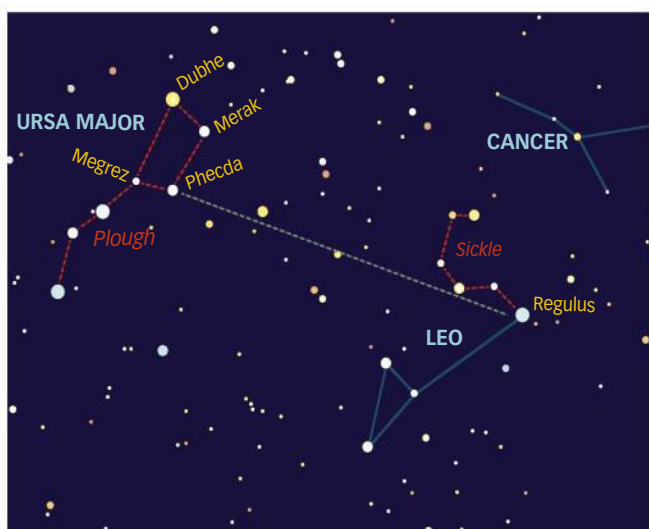
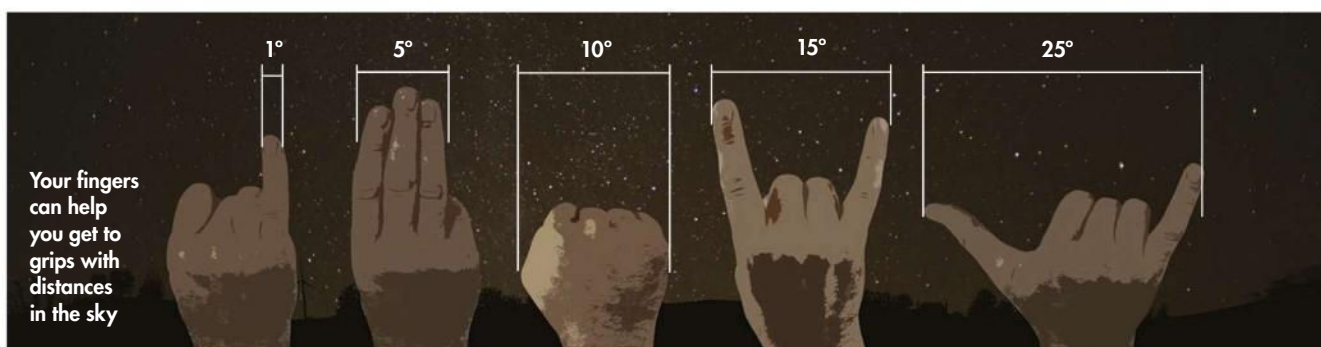
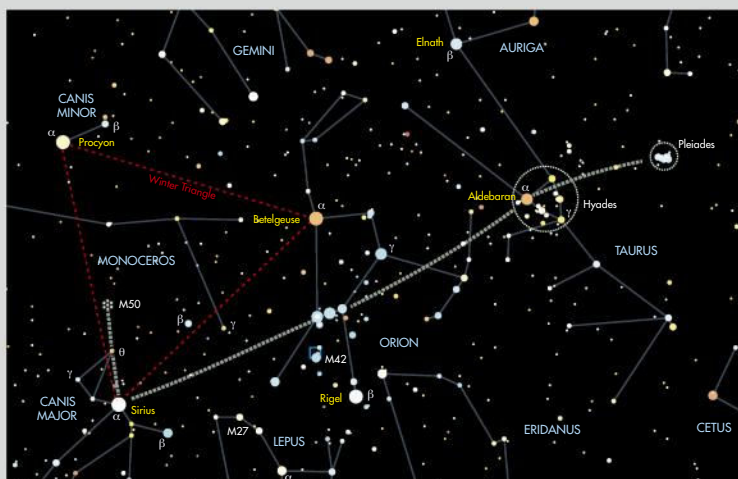
ADVANCED STAR HOPPING FROM ORION'S BELT

NAKED EYE Extend a line through Orion's Belt northwest for 22° , where you will find the bright orange star Aldebaran at one tip of a V of stars. This is the Hyades open cluster. Now extend it 14° farther on and you will find the Pleiades open cluster, commonly called the Seven Sisters.

NAKED EYE From Orion's Belt, look about 20° southeast to reach the bright star Sirius which, with Betelgeuse, is part of

the Winter Triangle asterism. Imagine that Sirius and Betelgeuse are the base of an equilateral triangle. At the other apex is the third star, Procyon.

BINOCULARS Start at Sirius and look 5° towards Procyon, where you will find the star Theta Canis Majoris. Nearly the same distance farther on lies M50, an open cluster that will appear as a fuzzy patch in your binoculars.



REGULUS IN LEO

To get to Leo (the Lion) you also start from Megrez, but this time trace a line through Phecda, the star below it in the Plough. Continuing on this line will take you to Regulus, the brightest star in Leo. The head of the Lion is made by an easily seen hook-shaped asterism called the Sickle that works up from Regulus.



CAPELLA IN AURIGA

To find Auriga (the Charioteer) start again from Megrez, but this time take a route through Dubhe, to its right. After an expanse of emptiness that includes the very faint constellation of Camelopardalis (the Giraffe) you will eventually arrive at the yellow star Capella, the brightest star of Auriga.

START STARGAZING THE RIGHT WAY

Practical advice for a good first night under the stars

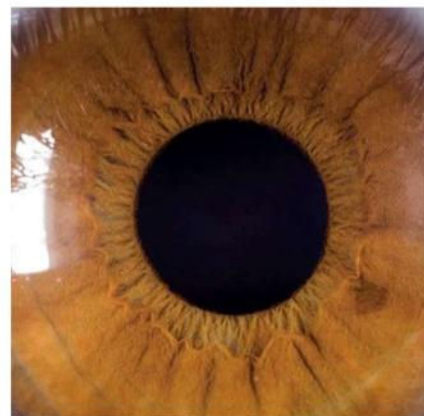


1. NO EQUIPMENT NEEDED

There is a widespread perception that to be a 'proper' astronomer you need to have a telescope. This is complete rubbish. There are a host of things you can see with the naked eye alone – from the constellations to meteors showers, the band of the Milky Way and even the occasional galaxy. If you want to take things further, consider buying a pair of binoculars before a telescope – you get to see more of the night sky without having to deal with the practicalities of setting up.

2. WRAP UP WARM

We know this sounds obvious, but astronomy involves a lot of time spent being still, so it's important to guard against the cold. Multiple thin layers of clothing are a good idea, as are waterproof shoes, a hat and gloves. If you have pages to turn or equipment (especially touchscreens) to operate, fingerless gloves may be best.



3. FIND SOMETHING TO LIE ON

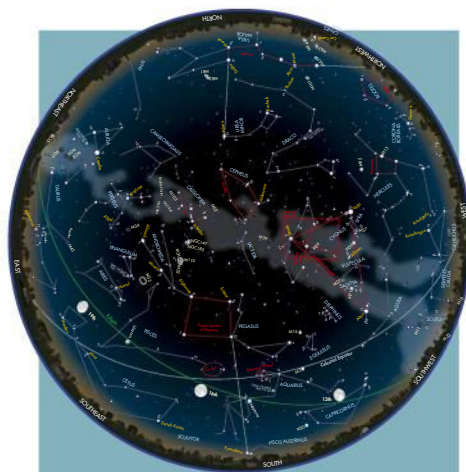
You'll find that you get neck ache within a very short amount of time if you stand still staring upwards at the sky. So avoid the pain entirely by finding

something you can lie back on. A reclining garden chair, a sunlounger or even an old-fashioned deck chair is ideal, but your spine will thank you even if all you have to hand is a camping groundsheet, a yoga mat or a blanket to spread over the grass.



4. LET YOUR EYES ADJUST

This is crucial. If you go outside from a brightly lit room, you'll probably only see a handful of stars. Wait and let your eyes adjust to the darkness – ideally for 30 minutes – and you'll notice an incredible difference. Doing so should allow you to see much fainter stars.

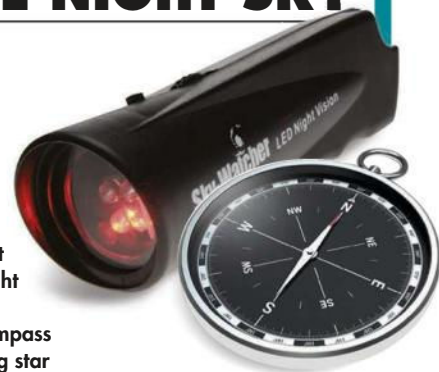


5. PICK UP A STAR CHART

We publish one of these in *BBC Sky at Night Magazine* every month, and they are a great way to learn your way around the night sky. You can begin by identifying patterns of bright stars. From there you can gradually learn your way around the constellations, and before too long they'll become familiar and you'll be able navigate your way around the night sky without reference to a book or chart. They frequently list the locations of prominent deep-sky objects, which, being dim, can be harder to locate.

6. TAKE A RED TORCH AND A COMPASS

Your eyes are dark-adapted, yet you'd still like to see charts and be sure that you're not about to step on a hedgehog. The answer is a red-light torch, as dark-adapted eyes are much less sensitive to red light than they are to white. You can buy dedicated red-light torches, or make a DIY one by taking a normal torch and fixing a piece of red acetate over the front. A compass will help you find north, and is useful not only in using star charts but also in setting up your telescope mount.



7. AVOID ARTIFICIAL LIGHTS

Make sure any light sources are obscured from your observing position, as they will prevent your eyes from acclimatising to the darkness properly. If you can get out to the countryside you can take advantage of properly dark skies – this will really make a difference.



8. TAKE YOUR TIME

The fact is that there is an awful lot to get your head around, and no one has ever looked at the night sky and instantly understood how to find their way around. Not even Sir Patrick Moore was immune to this; he did it by learning one new constellation each night.



ADVANCED TECHNIQUES

Get better views of night sky objects with these tips

AVERTED VISION

Averted vision is a way of seeing faint celestial objects through binoculars or a telescope more easily by looking using peripheral vision. This involves glancing to the side of your target rather than directly at it, to use your eye's more sensitive rod cells.

A good way to practice using averted vision is to seek out the Blinking Planetary Nebula, designated NGC 6826 (RA 19h 44m 48s, dec. $-50^{\circ} 31' 30''$). When viewed directly through a small telescope, the nebula's bright central star overwhelms the view; looking with averted vision reveals the nebula itself, which appears to 'blink' on and off as the viewer shifts their gaze.

LIMITING MAGNITUDE

It's really worthwhile getting to know the faintest stars you can see from where you live – in other words, the limiting visual magnitude of the skies above you.

As light pollution increases, so the number of stars you can see decreases. If your skies are very bad you may be limited to the second magnitude or worse, with only a handful of the brightest stars on show.

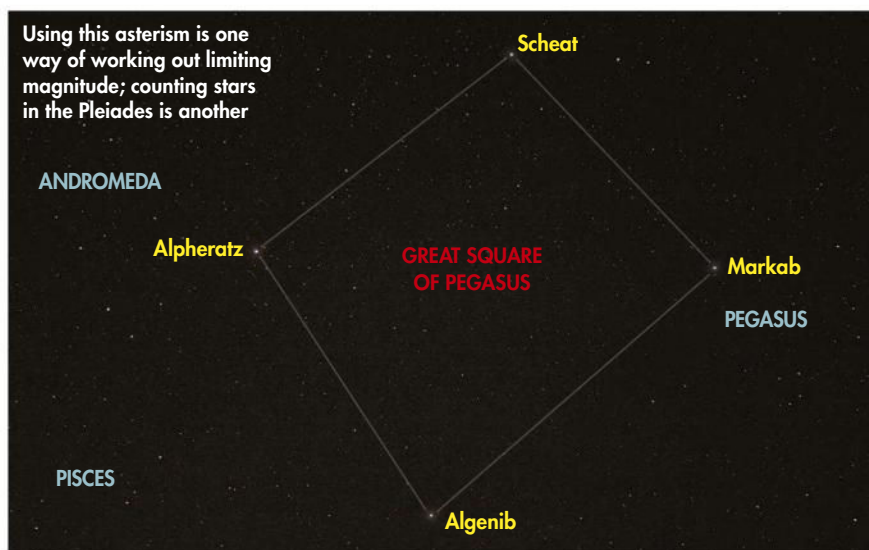
One way of determining your limiting magnitude is to use the Great Square of Pegasus asterism – it is comprised of four

stars, the dimmest of which is mag. +2.8. You need to wait for your eyes to adapt to the dark to do this accurately, so head outside a good 15 minutes in advance to acclimatise. Then look for the Great Square – with your eyes only – and count the number of stars you can see inside it. If you can't see any, then your limiting magnitude

is +4.0. If you can spot three, your site's limiting magnitude is +4.75; at five stars it is mag. +5.25; at nine stars it is mag. +5.75. If you can count all the way up to 13 stars, you can see down to mag. +6.0.

Try this on a few nights. You may find the atmospheric conditions are different each time, and this can affect what you can see.

Using this asterism is one way of working out limiting magnitude; counting stars in the Pleiades is another



SEEING AND ATMOSPHERIC TRANSPARENCY

The movement of the atmosphere can affect your ability to observe stars and planets to a surprising extent

The weather is generally considered to be the biggest hindrance to astronomy. What's the betting that the night you decide to head out for the night that spell of fine weather changes for the worse? So you'd have thought that when the skies finally clear, your problems would be over. Surprisingly, though, even a clear night may not be the best time to go out and observe.

The issue is the 'seeing'. In astronomy, this doesn't mean how you look at something. It's a term that describes how much the view you see through

your telescope is disturbed by what's going on in the atmosphere above you.

At times of good seeing, you'll get sharp, steady views through your telescope. But bad seeing produces turbulent, unstable telescope views of the Moon and shuddering, shaky images of stars. On the other hand, deep-sky objects like galaxies and nebulae aren't as badly affected by bad seeing.

This is thanks to the layers of moving air between you and the object you're looking at, the effects of which are magnified by your telescope. In the



“A sunset will have a jagged appearance thanks to sunlight moving through turbulent air”

atmosphere, air at different temperatures is always moving around and mixing together. Light travels through hot and cold air at different speeds, so it is continually bent this way and that before it finally arrives at your telescope all shaken and stirred.

Sometimes there are very few moments of clarity. One of the best ways to see this distortion is to watch the Sun setting on a clear horizon. It will have a jagged appearance, thanks to the sunlight moving through layers of turbulent air.

The other factor that affects observing conditions is the transparency of the night – just how clear the sky is. After it's been raining, the sky is transparent because the rain clears away particles of dust and smog from the air. However, when it's been raining it also tends to be windy, which means that the seeing is bad. You'll notice that the stars are twinkling because of this. Transparent conditions are, however, good for large, faint objects like nebulae and galaxies, which really benefit from the better contrast. Poor transparency generally means the air is steady with good seeing, but dust and particles are sitting in the still atmosphere. These conditions are good for looking at the Moon and stars.

A good way to think of seeing and transparency is to imagine a swimming

pool with a coin resting on the bottom. The water represents our atmosphere and the coin the starry object you're looking at. Through completely still water with no currents, the coin looks still, crisp and clear. In this case the seeing is perfect and so is the transparency. If the water is made to move – causing ripples – the coin's image will shake around; the transparency is still good but the seeing is bad. And if some milk is spilt in the pool so you can't see the coin very clearly, the transparency will be reduced.

It goes to show that you're at the mercy of the atmosphere... and that moments of clarity are a wonderful thing.

Clear and present

You can't do anything about 'high-level seeing' – the air currents far above you – but you can influence the 'low-level seeing' to create steadier air conditions immediately around you and your scope. Here's how:

- 1 Leave your scope outside to cool to the ambient temperature, eliminating any air currents in the tube.
- 2 Observe on grass rather than concrete. Concrete absorbs more heat from the Sun and radiates it out to the air above it for longer.
- 3 Air currents tend to stay low to the

ground, so it can be a good idea to raise up your scope on a platform.

4 If you build an observatory, make it using thin materials such as wood that can cool quickly.

5 The geography of your observing site affects how air behaves. Being near the sea gives you calmer air than if you're near a range of hills, where air is forced upwards, causing turbulence.

USING THE ANTONIADI SCALE

It's very useful to note down what the seeing is when you're observing. Many astronomers use the Antoniadi scale as a measure of what the atmosphere is up to. It's a five-point scale using Roman numerals. I indicates the best conditions, while V describes the worst.

- I Perfect seeing, without any quiver of turbulence whatsoever.
- II Slight shimmers; moments of stillness last several seconds.
- III Average seeing; larger air tremors blur the view.
- IV Poor views, with constant troublesome undulations of the image.
- V Bad views with severe undulations; so unstable that even quick sketches are out of the question.



HOW FAINT CAN YOU SEE?

Atmospheric conditions have an impact on the faintness of the stars you can observe. Use the chart here to check the faintest stars you can see by looking at Ursa Minor on a very clear night to work out your limiting magnitude. This is the faintest star magnitude, or brightness, that you can see from your location – higher numbers mean fainter stars.

Work out your limiting magnitude by finding the dimmest stars you can see in Ursa Minor on a very clear night. Under a perfect sky you should be able to spot mag. +6.5 stars

HOW TO DEAL WITH LIGHT POLLUTION

Don't despair of your garden – there are many ways to fight glow and glare

Britain is blossoming with accredited dark skies. It was only in late 2015 that a 2,170km² chunk of Snowdonia National Park became the third swathe of Wales to gain endorsement from the International Dark Skies Association, meaning that nearly 18 per cent of the country now boasts night skies recognised for their lack of light pollution. It is the most recent member of a slowly growing club, joining Exmoor in Devon, Galloway Forest Park in Dumfries and Galloway, and the Isle of Sark in the English Channel to name a few.

These designations are great news in terms of protecting the skies for future generations, and indeed for a spot of practical astronomy if you are lucky enough to live within travelling distance of any of them. But for many of us, stargazing is the preserve of the back

garden, and that often means dealing with light pollution.

This vexation comes in two flavours: sky glow, the rusty orange haze cast by the massed lights over a wide area, and local glare from line-of-sight sources – nearby streetlights, security lights, car headlights, even the light emanating from your neighbours' windows. Sky glow washes out the night and blots out the stars, while local sources are more prone to ruining your night vision. Under dark skies you can see stars down to mag. +6.5 with the naked eye, but light pollution can cut this to just a handful of first magnitude stars. Another common casualty is the pale band of the Milky Way, the river of stars that stretches high across the autumn skies.

Not surprisingly, the worst places for light pollution are the major towns and

cities. However, stargazers who live in more rural locations can be just as bothered by the annoying bright light from a neighbour's badly adjusted security light. Thankfully, there are a few things you can try to mitigate their unwanted effects.

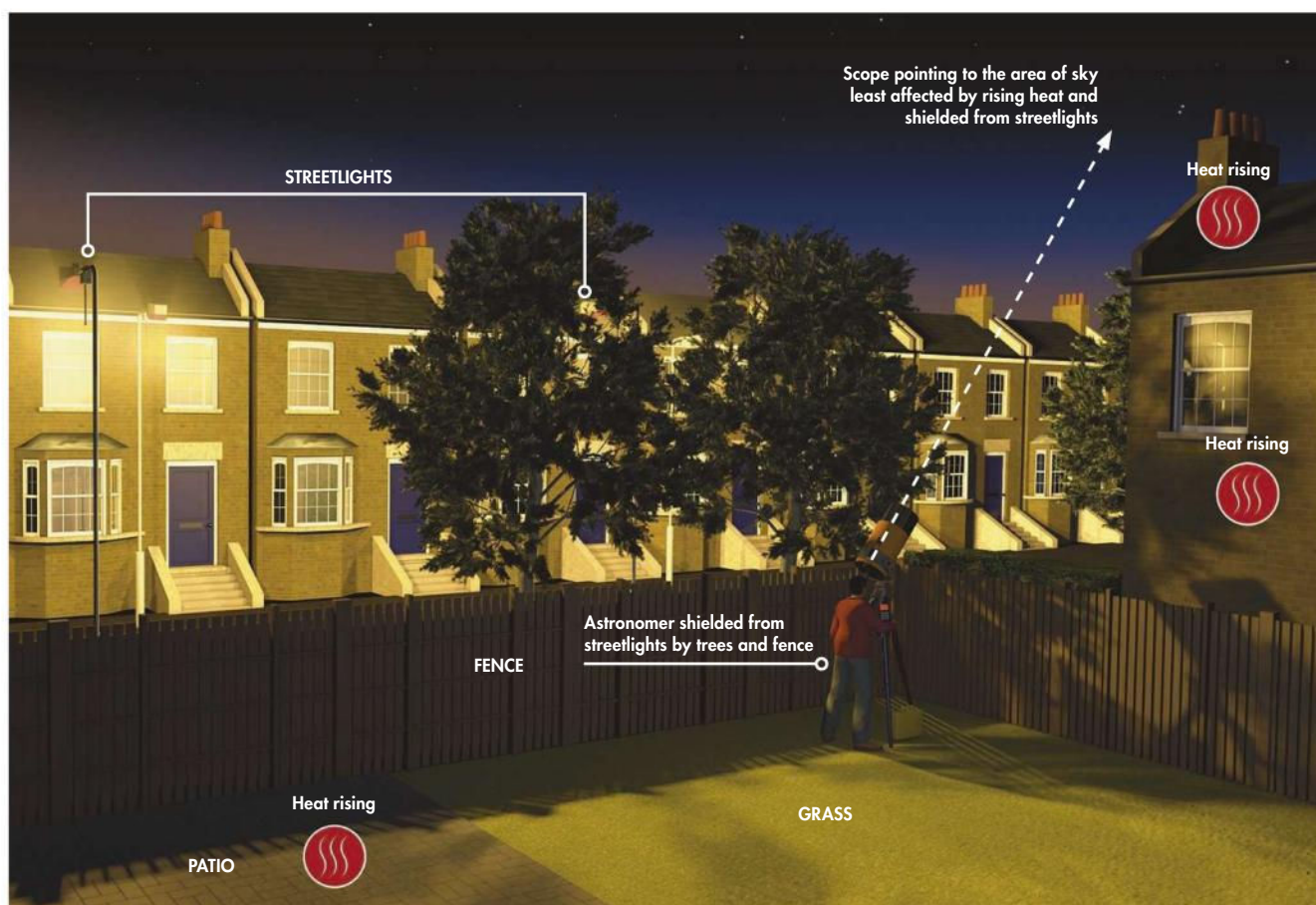
Focus on what you can fix

For local sources of light pollution, your biggest consideration is where you position your scope in your garden. You need to find a spot that puts a barrier between yourself and the irksome source of glare. That barrier could be anything – a fence, a tree, the side of a building – so long as it isn't so big it also masks the part of the sky you want to look at.

If no suitable cover already exists, consider making some. A simple 'shield' consisting of a frame of wood or plastic

The light pollution is particularly troublesome over cities, but there will be pockets of darkness wherever you are





Your scope should ideally be situated on grass, shielded from external lights and pointing between or away from heat sources such as rooftops

pipework with blackout cloth stretched across it can work wonders, though make sure you brace the legs. The last thing you want is for it to catch the wind and clatter into your setup mid session. If DIY is not your thing, ditch the frame and simply hang the blackout cloth from a washing line, a garden trellis or similar, though again you will need to weigh it down to forestall lift-off.

Getting to know your neighbours better can also go a long way, if the lights that are causing you consternation come from their home. Many astronomers report reciprocal arrangements that work well in this regard – in return for feeding the cat while they are on holiday, they may acquiesce to, say, drawing their curtains when you are in the garden observing. You can only ask.

Your next consideration should be optimising the equipment you have, and this can help you deal with both glare and generic glow. Your goals are to maximise the contrast of what you see and minimise the ingress of stray light. Opt for eyepieces that have eye guards to block extraneous light, and make sure their lenses are free from eyelash grease as this can degrade the view. As an

alternative to eye guards, throw another piece of blackout cloth over your head, just as a Victorian photographer would. It may look a little odd (another great reason to tell your neighbours what you are up to) but it can help you establish and preserve your night vision.

Adding a light pollution filter to your setup, and depending on your target, colour or narrowband filters, can increase clarity and enhance detail. At the opposite end, a dew shield can also help stop light getting in; if you don't own one, you can make one cheaply from a rolled up camping mat. If the glow above you is so bad that you have trouble navigating to your intended targets in the first place, purchasing a Go-To mount may be the least stressful way to reach them.

In many places there is a noticeable drop off in sky glow after midnight as more and more people and businesses turn off their interior lights, meaning the wee hours often offer better views. You may also find that your local authority turns off streetlights at a set time. If sky glow is a particular problem, make sure you wait until your chosen target is well clear of the horizon before you attempt to view it.

WHAT IF MY GARDEN IS HOPELESS?

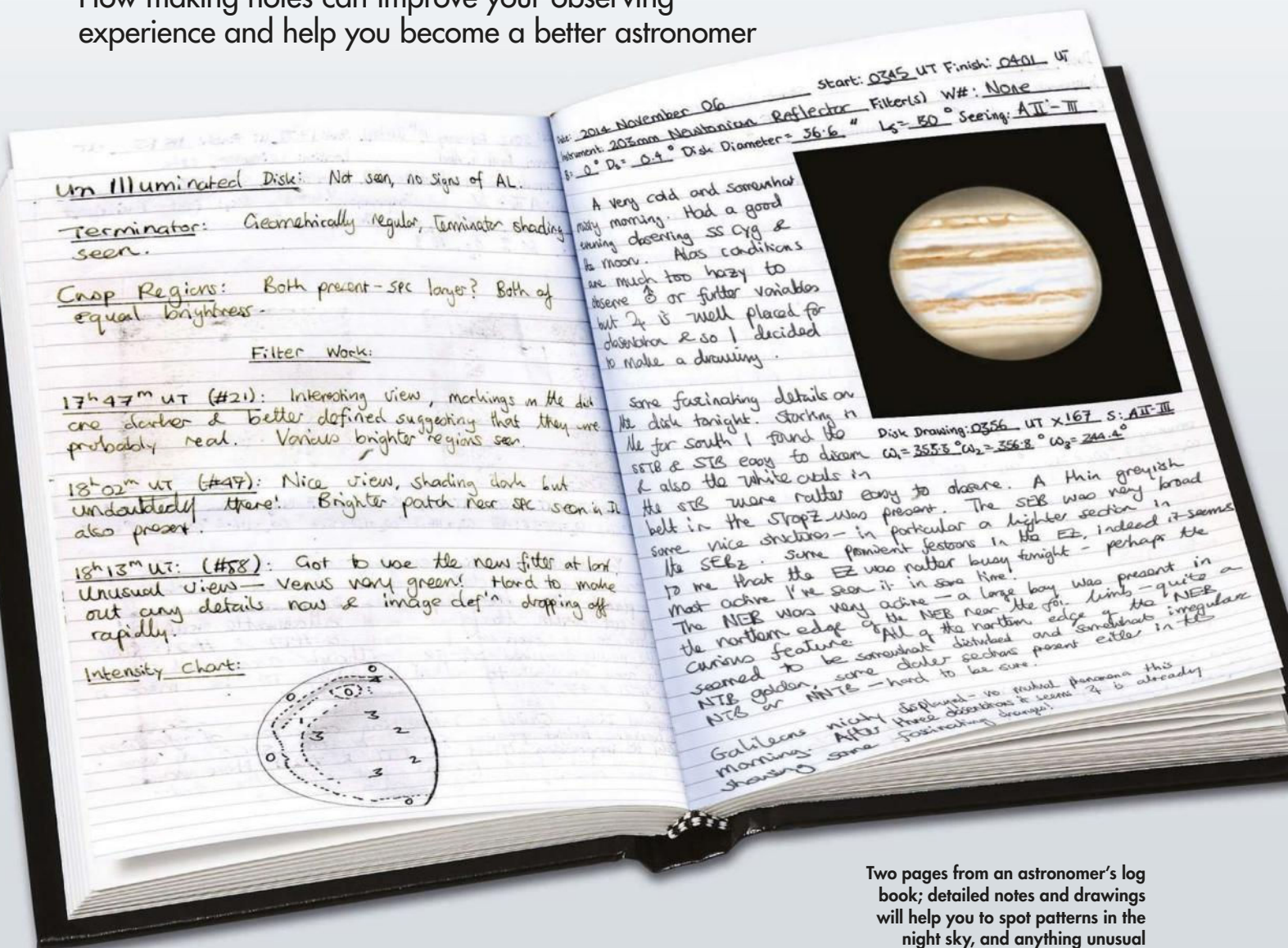
If you truly cannot find a way to cut out the glare, see past the glow or simply don't have the space to create a dark corner, try looking for an alternative, darker location nearby. It's imperative to do some research before heading out in this case: once you have found a potential location, make sure that you have a right to be there and above all that it is safe at night, especially if you will be observing alone. Another option is to join your local astronomical society. Many host observing evenings for members, and it is likely that some of your fellow stargazers will be able to suggest some good observing spots in your area.



Get out of town to maximise darkness

KEEPING A LOG BOOK

How making notes can improve your observing experience and help you become a better astronomer



Two pages from an astronomer's log book; detailed notes and drawings will help you to spot patterns in the night sky, and anything unusual

The journey from absolute beginner to seasoned amateur astronomer is full of poignant personal cosmic discoveries. Your observing adventures out there in the Universe will be marked by a number of important first-time events – locating a much sought after Messier object, for example, or perhaps seeing the polar ice caps of Mars for the first time. However, if you are to build on these

first glimpses, you must accurately record what you have seen.

Keeping a log book will transform you from a casual viewer to a reliable observer. Observation is much more than just looking through the eyepiece of a telescope. By writing up your observations in a systematic way you'll find that your eyesight sharpens; you can look back and see how your

observing and drawing skills have improved; you'll have a tangible past on which to build. By repeating observations, old friends will be revealed in a new light, their subtle aspects slowly coming to the fore. All of this will make astronomy much more rewarding.

There's also a scientific aspect to keeping a log book. You may be able to provide confirmation of a rarely observed

WHAT TO RECORD

DATE The full date in the format yyyy-mm-dd.

TIME The time of each observation in UT.

TELESCOPE The size of telescope and its type (Newtonian, Schmidt-Cassegrain, etc).

MAGNIFICATION The powers you use for drawings and observing.

EYEPIECES Focal length, and whether you used a star diagonal or Barlow lens.

FILTER WORK Include the Wratten number (printed on the side of the filter) of any filters used in your observations.

SEEING This is a measure of how steady the atmosphere is. Use the Antoniadi scale from I-V, where I is a perfectly sharp image and V is an unfocused blob.

OTHER CONDITIONS

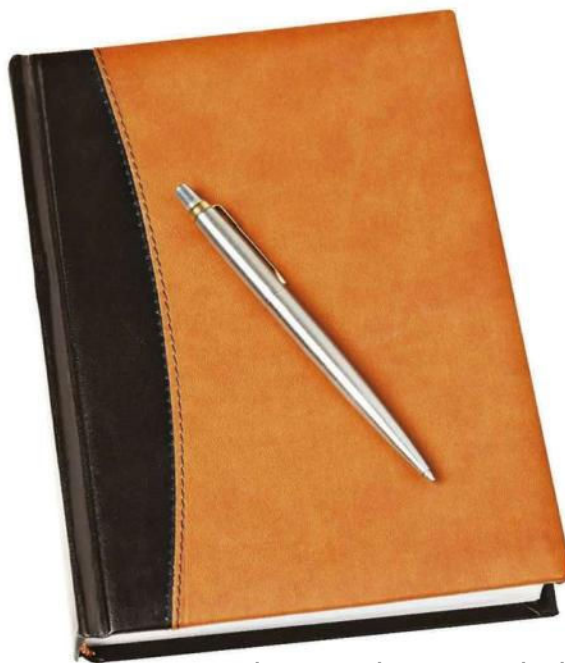
Any cloud or mist present, moonlight, the level of light pollution at your location, etc.

TARGET-SPECIFIC

DETAILS For planets, note the value of the central meridian, phase (if applicable) and disc size. For deep-sky objects and comets, indicate north in any drawings and include the constellation. Variable stars require magnitude estimates.

PERSONAL THOUGHTS

Make a note of anything else that strikes you as interesting or unusual.



Make sure you choose a strong hardback notebook that can stand regular use; consider investing in several for different targets

phenomenon such as a bright fireball, or the beginnings of a dust storm on Mars. If you have no accurate record of what you have observed, you may never know if you have seen something important.

By recording your observations in a consistent manner, you'll find that your whole approach to astronomy shifts into a much more rewarding pursuit: rather than just checking off objects you have seen, you can begin to study them properly. This will allow you to

specialise and decide which aspects of astronomy interest you the most. There are still many areas in which amateurs can make useful contributions to astronomy, including planetary and variable star work, provided their observations are recorded systematically.

A tome to last

The log book itself should be sturdy, hard backed and contain good quality paper. It's worth spending some money on it as

cheaper books can fall to pieces after a couple of months under the British winter skies! Loose-leaf observations in ring binders should be avoided, as it is only a matter of time before individual entries become lost.

What you record will largely depend on what you are observing. Although there are some standard things you must always note down – such as the date, time and the details of your telescope – some are specific to the type of object you are looking at. Planets, for example, require drawings that provide an important visual impression of what you've seen, along with details such as phase and disc size. Variable stars require no drawings, but will need magnitude estimates and details of the finder chart used.

For this reason, you might want to keep a log book for each object. Perhaps separate books for all the planets, variable stars, solar work and the deep sky. A good way to work can be to make rough drawings and observations outside, then a neat copy in your log books indoors afterwards. This makes the layout easier, with drawings on one page, and written notes on the following. Make your drawings on a separate piece of paper and stick them into your book, as you may need a few attempts at rendering them.

Your log books will be your observing legacy – you should regard them as one of amateur astronomy's essentials.

THE VALUE TO SCIENCE

Keeping a log book is more than a personal endeavour: the details you record can help contribute to real science. Variable star enthusiast Gary Poyner has clocked up a total of 269,753 variable star observations. The records from his log books allow light curves of a number of variables to be extended back into the 1970s. One of the greatest visual observers was British amateur George Alcock, who discovered five comets and five novae with binoculars – the last at the age of 78. His logs were full of meticulous notes and fine drawings of the objects he'd discovered.



George Alcock was a firm proponent of binoculars – all of his discoveries were made using them

BBC

Sky at Night

MAGAZINE

SAVE WHEN YOU SUBSCRIBE
TO THE DIGITAL EDITION



Available from



Download on the
App Store



Available on
kindle fire



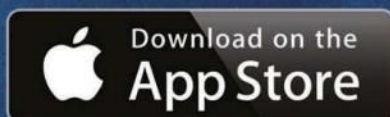
GET IT ON
Google play

zinio™

The perfect addition to your stargazing, *BBC Sky at Night Magazine* is your practical guide to astronomy, helping you to discover the night skies, understand the Universe around us and learn exciting techniques for using your telescope.



Enjoy our Premium App experience now available from



zinio™

BBC
Sky at Night
MAGAZINE



CELESTRON®

TECHNOLOGICALLY SUPERIOR



ADVANCED VX

A SOLID FOUNDATION DESIGNED FROM THE GROUND UP

Engineered from the ground up with astroimaging in mind, the new Advanced VX series from Celestron sets a superior standard in mid-level telescopes. Advanced VX provides you with many of the features found on Celestron's most sophisticated German equatorial mounts, at an extremely affordable price.



12031 – Advanced VX
8 EdgeHD

Camera not included

12026 - Advanced VX 8 SCT
12031 - Advanced VX 8 EdgeHD
12046 - Advanced VX 9.25 SCT
12067 - Advanced VX 11 SCT
12079 - Advanced VX 6 SCT

22020 - Advanced VX 6 R
32054 - Advanced VX 6 N
32062 - Advanced VX 8 N
91519 - Advanced VX Mount



StarSense™ AutoAlign Accessory

Upgrade your Celestron computerised telescope to a fully automatic computer set up*

- Set your telescope outside, press 'Align' on the StarSense hand control, and sit back. No further user involvement needed!
- StarSense uses an on-board digital camera to scan the sky.
- In about 3 minutes StarSense will gather enough information to triangulate its position and align itself.
- No need to identify or manually locate alignment stars in the sky. StarSense will automatically align your telescope.
- Sky Tour mode will slew to all the best stars, planets, galaxies and more based on your exact time and location.
- Provides advanced mount modelling.



* See website for
compatibility

Celestron SkyPortal™ WiFi Module

Control your Celestron computerised telescope using your smart device*

- Control your telescope right from your device using SkyPortal Wi-Fi module and SkyPortal App.
- Tap any celestial object you see in the sky to identify it immediately.
- Slew your telescope to over astronomical 120,000 objects.
- Works with Celestron's brand new planetarium App, SkyPortal.
- SkyPortal App turns your smartphone or tablet into your own personal planetarium.
- You can listen to hundreds of included audio descriptions and view hundreds of images through your device.
- iOS and Android compatible.
- Download the free SkyPortal App and start discovering today!



iPhones shown
not included



* See website for
compatibility

Available from specialist astronomy retailers and selected other dealers nationwide.
Celestron is distributed in the UK & Ireland by David Hinds Limited. Trade enquiries welcomed.

www.celestron.uk.com

WHAT TO USE

EQUIPMENT AND ADVICE

To start your astronomical adventure, all you need to do is walk outside on a clear night and look up. But there will come a time when you feel you need to get closer – it happens to us all. For this you'll need a pair of binoculars or a telescope. These optical aids do two things: they collect more light from dim and distant stars than your eyes alone do, and they magnify the view.

In this section, we'll take you through the best types of equipment

to train on the night skies to get the best views. We'll look at why it's best to begin with binoculars before moving on to a telescope, and why the mount that a telescope tube sits on is every bit as important as the lenses or mirrors that gather up all that starlight.

We'll also take a tour of the important accessories you need to get great views, such as eyepieces and filters, and give you a primer on how to take your first steps in astrophotography.





INTRODUCING PLANISPHERES

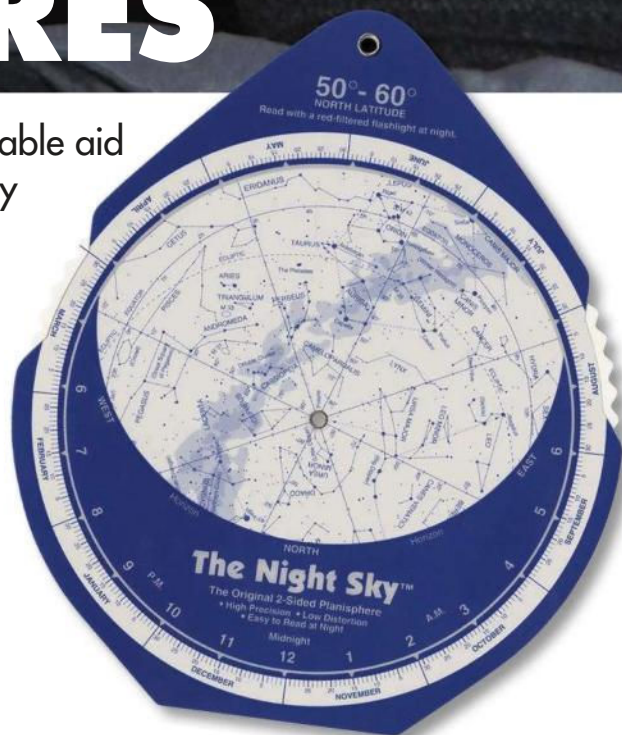
Even in the digital age, the planisphere is an invaluable aid when you need to get your bearings in the night sky

As a budding stargazer, a planisphere is one of the greatest aids to helping you find your way around the night sky. They don't look like much – usually they're just two discs of cardboard or plastic fastened together with a central pin. But this deceptively simple design belies the fact that a planisphere allows you to work out which bright stars are in the night sky on any date and at any time throughout the year.

This basic knowledge is useful for casual stargazers and more serious

amateur astronomers alike. For example, it could help you to learn the constellations or even just identify a bright star you can see at a particular time. It can also be a useful aide-memoire when planning an observing session.

Although the two discs are pinned together, they can still be rotated independently of each other. Printed over most of the lower disc are the stars,



constellations and brighter deep-sky objects that you can see from a given latitude. Marked around the outside of this lower disc are the days and months.

Talking circles

The upper disc will be slightly smaller than the lower one or will have a clear rim, so you can still see the day and month markings underneath. It also has an oval window in it, revealing part of the star chart on the lower disc. The edge of this window represents the horizon with appropriate north, south, east and west markings, and everything within it is the visible sky.

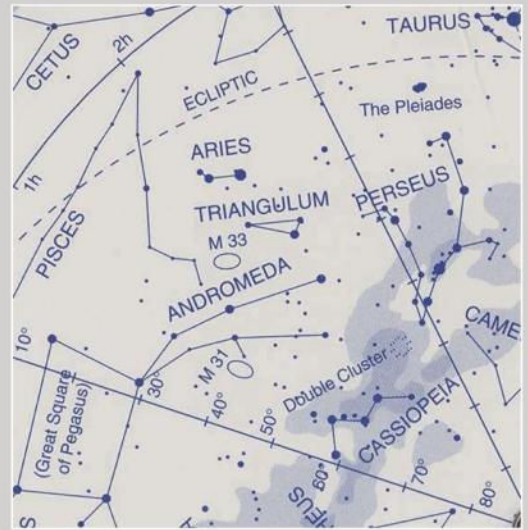
Just like the lower disc, the upper disc has markings around its edge. In this case, they denote the time of day. By lining up the date and time, the stars visible in the window will match the ones in the night sky at that time. We explain how to use the planisphere in the step-by-step guide below.

On some planispheres, you may notice that some of the stars (particularly those near the southern horizon) are rather stretched out. This is because the sky is 3D and it is being forced onto a 2D disc, so it has to be expanded towards the edge of the chart. This tool should be an essential part of your night-sky

THE PLANET PROBLEM

Why can't I use a planisphere to find the planets or the Moon?

Planispheres show objects that are 'fixed' in the night sky relative to Earth – that's why they can be used year after year. However, this means that they can't predict the location of planets or the Moon. Some manufacturers try to overcome this by printing details of planetary locations for several years on the back, but there is also a line printed on the chart itself that can help. The ecliptic, often shown as a dotted line, marks the plane of the Solar System, in which most of the planets orbit the Sun. If you discover a 'star' in the sky that's not shown on the planisphere, then it is probably a planet.



arsenal. Planispheres are cheap, easy to use, robust (plastic ones more so), lightweight, portable and – best of all – they don't need electricity.

The one important point to keep in mind when using one is that planispheres are designed to work at specific latitudes. If you try using one too far north

or south of the location it has been designed for, you'll find that the stars don't appear in the right positions. UK latitudes vary from 50°N (southern England) to 60°N (northern Scotland). Both Philip's and the David Chandler Company produce planispheres for this region.

HOW TO USE A PLANISPHERE

1 GET YOUR BEARINGS

There's one thing you need to know before using a planisphere, the cardinal points from where you live. If you don't have a compass, use the Sun. It rises roughly in the east and sets roughly in the west



2 SET THE PLANISPHERE

Let's say you're heading out at 9pm on 15 January. Align the 9pm marker on the upper disc with the 15 January marker on the lower disc. The stars in the oval window should now match those in the skies above.



3 HOLD IT UP

To start with, look north, holding the planisphere so that the word 'north' is at the bottom. If you change the direction you're facing, move the planisphere round so that the corresponding compass point is now at the bottom.



4 STAR HOPPING

The central pin represents Polaris and the north celestial pole. Just to its lower right will be the seven bright stars of the Plough. Use these and the five stars forming the W shape of Cassiopeia to get to know the constellations.



THE VALUE OF BINOCULARS

Telescopes aren't the only option for observing astronomical objects

Starting out in astronomy and wondering what to buy for your first telescope? There's a simple answer to that question: don't buy one, buy two. Two small ones that are joined with a hinge so that the distance between them can be adjusted to exactly match your eyes. We are of course talking about binoculars – a valuable tool in the armouries of most active observers.

There are hundreds of astronomical bodies that a pair of binoculars will bring into view for you. Not only will they let you see many more objects than you can with the naked eye, but the detail and colour in those objects become a lot richer.

With binoculars, the Coathanger asterism in Vulpecula actually looks like a coathanger and the Orion Nebula becomes a fantastically detailed painting of light. The Milky Way is no longer a tenuous glowing band, but a knotted tangle of stars, interspersed with mysterious dark patches. Albireo goes from being an ordinary-looking star that marks the head of Cygnus

to an exquisite binary juxtaposition of gold and sapphire. And you can easily see galaxies by the light that left them millions of years ago, when our ancestors were thinking about leaving the trees.

Binoculars are still suitable even if you want to do 'serious' astronomy. There are

that the binoculars let you find as you cast your gaze among the stars. Before you even realise it, you have begun to learn the sky and you'll soon be able to navigate around it better than the entry-level Go-To telescope you nearly bought instead.

Best of all, you can have this complete observing system for two eyes for less than the price of one reasonably good telescope eyepiece.

“Binoculars are classified by two numbers: their magnification and aperture”

What to look for

Binoculars are classified by two numbers that refer to their magnification and aperture. A 10x50 pair of binoculars has a magnification of 10x, and each of the objective lenses has an aperture of 50mm. These numbers also enable you to calculate the size of the circle of light – or 'exit pupil' – that emerges from the eyepieces: all you have to do is divide the aperture by the magnification. This means a 10x50 pair of binoculars has an exit pupil of 5mm. The exit pupil should be no larger than the dark-dilated

variable star observing programmes specifically for binoculars, and their portability makes them ideal for taking to the narrow track where a lunar graze or asteroid occultation is visible.

Alternatively, you could wrap up warm, lie back on your garden recliner and just enjoy the objects



Don't be tempted to go for the biggest binoculars you can afford – larger pairs are harder to hold steady, and large night-sky features can be better seen with less magnification

CAN I USE ANY OLD BINOCULARS?

In principle, yes: even plastic-lensed 4x20 toy binoculars can show you astronomical objects that you otherwise couldn't see, such as the moons of Jupiter. If you already have a pair of small binoculars, for example a 6x30 or 8x32 pair, try them out under the stars: you'll be amazed at how much more you can see. The optical quality will also make a difference and you may find that there are things you can see with good-quality small binoculars like 8x42s that are beyond the capability of an entry-level 15x70. But avoid zoom binoculars: good ones don't exist.



Even toy binoculars give a decent view of the night sky if the kids will let you have them



The bigger your binoculars get, the harder they become to hold steady. A mount will provide a stable viewing platform for larger binoculars, and camera tripod adaptors are available

pupils of your eyes: a pupil of anywhere between 4–6mm is fine for your first pair of binoculars.

Larger apertures potentially show you more, but may need mounting if you want steady views over prolonged periods. Common sizes are:

- **8x40, which almost anyone over the age of 10 can hold steadily**
- **10x50, which most adults can hold**

steadily (this size is a popular compromise between size and weight)

- **15x70, which really needs to be mounted, although they can be briefly handheld**

You should also check that the distance between the eyepieces, or 'interpupillary distance' will adjust to your eyes. If you wear glasses, ensure that the binoculars have enough distance

('eye relief') from the eyepiece to your ideal eye position; 18mm or more should be fine.

There are two basic types of binoculars: Porro-prism and roof-prism. In any price range, roof-prisms are lighter, but Porro-prisms tend to have better optical quality. Once you've decided on size and type, get the best quality you can for your budget and start exploring the night sky.

BETTER THAN A TELESCOPE?

If your passion is planetary detail, close double stars, globular clusters or planetary nebulae, then consider buying a telescope. But for the rest of the visible Universe, binoculars are the better option. Setting up handheld binoculars takes a few seconds, and even mounted ones can be set up in a few minutes, so you'll be observing long before your Go-To telescope-using buddies are ready to start.

Many objects are ideally framed in the wider field of handheld binoculars: asterisms like Kemble's Cascade or the Leaping Minnow overflow most telescope fields, as do large open clusters such as the Pleiades and the Beehive Cluster. Even large faint objects like the Triangulum Galaxy and the North America Nebula can be easier to see in budget 10x50 binoculars than in amateur telescopes of several times the price.



The Pleiades (left) and the Beehive Cluster (right) are popular targets for binoculars

YOUR FIRST TELESCOPE

Buying a telescope can sometimes be a daunting task. We cut through the jargon to help you make up your mind

Astronomy is an immensely rewarding adventure full of exploration and discovery. Planets, stars, nebulae and galaxies, among many other wonders, are all waiting to amaze and inspire you. But buying your first telescope is not always an easy business. There's

an array of equipment and technical terminology waiting to confuse and entice you as you start your journey of discovery. We'll take a straightforward look at the four most common types of telescope and how they work, to give you a better idea of your options.



ALL PHOTOS: PAUL WHITEFIELD

Investing in a scope will let you explore many more of the marvels in the Milky Way

REFLECTOR

Reflectors were invented by Sir Isaac Newton and use a specially curved main mirror to collect celestial light. In the Newtonian design (shown here), the light collected by the primary (main) mirror is reflected and focused back up the telescope's tube to a much

smaller, flat, 'secondary' mirror supported by wires in the centre of the tube; this secondary is angled at 45° to send the light beam out to the side, passing through a focuser and eventually into an eyepiece, which is what you look through.

SECONDARY MIRROR

The secondary mirror is located towards the front of the telescope tube and is set at a 45° angle. It reflects the light into the focuser, which is located on the side of the tube.

SLOW-MOTION CONTROLS

Slow-motion controls allow you to move the telescope manually in one or both axes. They allow you to carefully place a celestial object in the centre of the eyepiece's field of view and then keep it there.

COUNTERWEIGHTS

One or more counterweights are necessary to balance the telescope on the mount. This reduces the strain on any motorised drives and can prevent the scope from falling over.

JARGON BUSTER

APERTURE

The most important specification of a telescope. Aperture is the size of the main mirror or lens, usually given in inches.

MOUNT

The mount holds the telescope and allows you to point it at the sky. There are two main types:

EQUATORIAL

Mounts aligned to the night sky's axis of rotation. They use a coordinate system mapped onto the sky similar to longitude and latitude.

ALTAZIMUTH

Mounts that move in two axes: azimuth (measured in degrees from north) and altitude (up and down from 0° at the horizon to 90° right above your head).

FINDERSCOPE

The finderscope helps you to home in on your target. It can either be a miniature telescope with a wide field of view or a zero-magnification red-dot finder.

FOCUSER AND EYEPIECE

The focuser allows you to adjust the position of the eyepiece in order to focus the view of what you're looking at. Eyepieces enlarge the view produced by the telescope. Different eyepieces can be used to increase the apparent size of your target.

TUBE RINGS AND DOVETAIL BAR

The tube rings hold the telescope tube and allow you to rotate it to a suitable viewing position. The rings attach to a 'dovetail' bar (the black bar running between the two tube rings), which is used to secure the tube to a mount.

PRIMARY MIRROR

Light from distant objects is collected by the primary (main) mirror, which is at the bottom of a Newtonian telescope's tube. The mirror is specially curved so that it focuses light back up toward the secondary mirror.

POLARSCOPE

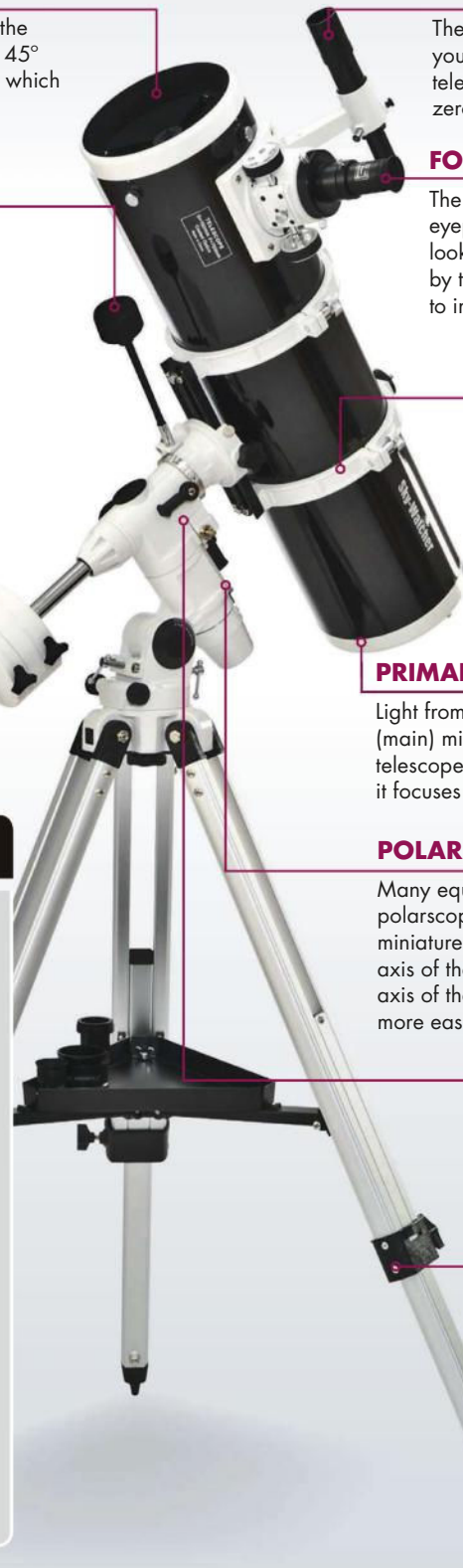
Many equatorial mounts have a built-in polarscope. The polarscope is effectively a miniature telescope that allows you to align one axis of the mount very accurately to the rotation axis of the night sky, allowing you to track the stars more easily.

MOUNT HEAD

The mount head for a Newtonian telescope is usually an equatorial design (see left). This allows you to align the mount to the night sky to track stars more easily.

TRIPOD

The tripod provides the support for the whole system. They are usually made of aluminium and have adjustable legs so that you can vary the height of the telescope for ease of use. The tripod needs to be stable and give firm support.



REFRACTOR

Refractors are the oldest and simplest telescope design – this is the type used by Galileo to record the phases of Venus, among other things. Refractors have a curved lens at the front, which focuses the

light down the tube directly to the focuser. A star diagonal, which bends the light through 90°, is often added between the focuser and the eyepiece to make viewing more comfortable.

DEW SHIELD

The dew shield protects the objective lens from becoming dewed up by moisture in the atmosphere. It also helps prevent stray light entering the tube and scattering off the objective lens, which would degrade the view.

OBJECTIVE LENS

The objective (main) lens is located at the front of the telescope tube. It focuses the light down the tube to the focuser. Modern lenses are often multicoated to provide better light transmission.

FOCUSER

The focuser allows you to make the image produced by the telescope sharp. The focuser on a basic refractor is often a 'rack and pinion' design, which has two thumbwheels for easy adjustment.

MOUNT HEAD

Like the reflector on the previous page, this refractor has an equatorial mount head design. However many basic refractors use simple altazimuth mounts.

EYEPIECE

Most beginners' scopes use eyepieces with a 1.25-inch barrel. You can usually place them directly into the focuser, though many people add a star diagonal for comfort.

STAR DIAGONAL

If the refractor has a long focal length the eyepiece can end up being quite low to the ground and uncomfortable to look through. A star diagonal redirects the light by 90° to provide a better viewing experience.

TRIPOD

Like reflectors, refractors need strong and sturdy tripods that don't wobble.

JARGON BUSTER

FOCAL LENGTH

The focal length is the distance between a telescope's main mirror or lens and the point at which light is brought to focus. For a given eyepiece, long focal length scopes show a narrower (more zoomed-in) view, whereas short focal length scopes give a wider field of view.

EYEPIECES

You look through the eyepiece to see celestial objects. The view can be magnified or reduced by using different eyepieces. Be warned, it's not all about magnification; you should choose the right eyepiece to use based on the observing conditions and the limitations of your telescope (such as how bright the view is through the eyepiece).

DOBSONIAN

SECONDARY MIRROR

The secondary mirror redirects the light path through 90°, out towards the side of the tube to the focuser.

TUBE ASSEMBLY

The tube assembly houses the secondary and primary mirrors. The focuser and finderscope attach on the outside. Some Dobsonians use a truss system rather than an enclosed tube.

ALTAZIMUTH MOUNT

Dobsonians use an altazimuth mount, where one axis tilts up and down and the other rotates horizontally.

FINDERSCOPE

The finderscope is a miniature telescope with a wide field of view that allows you to home in on your target.

The Dobsonian telescope is a reflecting telescope mounted on a simple but effective altazimuth mount popularised by amateur astronomer John Dobson in the 1960s. It sits in a box (or cradle) that allows it to be tilted up and down. The box

itself is mounted on a rotatable platform, so you can turn the telescope around in azimuth. Basic Dobsonians can't track the stars, but their simple design means you can generally get a larger aperture telescope for your money.

FOCUSER AND EYEPIECE

As in the Newtonian design, the eyepiece and focuser assembly sits at the top of the tube and juts out from the side of the telescope.

PRIMARY MIRROR

The primary mirror collects and focuses the light from distant celestial objects and reflects it back up to the secondary mirror.

CATADIOPTIC

Catadioptric, or compound, telescopes use a combination of a mirror and a front corrector lens to capture and focus celestial light in a compact and much shorter tube than refractors or reflectors. Light emerges from the rear; a star diagonal and eyepiece are used for comfortable viewing position. Popular designs include the Schmidt-Cassegrain and Maksutov-Cassegrain. Compound scopes can be mounted on equatorial mounts, but are often found on altazimuth Go-To mounts.

JARGON BUSTER

GO-TO

Some mounts possess motorised drives and computer handsets that are capable of aligning and controlling a telescope as well as pointing it at selected celestial objects. These 'Go-To' mounts make viewing many objects light work, however it can be a hindrance to learning your way around the sky if you use one when starting out.

CORRECTOR PLATE AND SECONDARY MIRROR

The corrector plate is at the front of the tube. It both corrects the light path and supports the secondary mirror.

PRIMARY MIRROR

The primary mirror collects and reflects light from celestial objects. It has a central hole allowing the light to pass through it from the secondary toward the focuser and eyepiece.

EYEPIECE AND STAR DIAGONAL

In this design the eyepiece and star diagonal are located at the rear of the telescope.

GO-TO HANDSET

The mount is controlled by a Go-To handset, which holds a large database of celestial objects. You choose one, the telescope aims itself at it.

GO-TO MOUNT

The electronic Go-To mount carries the telescope, and is specially geared to allow fine and fast slewing rates for moving around the sky.

KNOW YOUR SCOPE STATS

Get to grips with the often mysterious figures that describe the optical performance of your telescope – focal length and focal ratio

1. FOCAL LENGTH

The focal length of a refracting telescope is the distance between its lens and the place where light rays from that lens are finally brought to a focus, known as the focal point. For a reflecting telescope, simply swap the word 'lens' for 'mirror'.

Focal length is one of the important numbers if you want to find out what magnification you are viewing the night sky with. The magnification is the focal length of your telescope divided by the focal length of your eyepiece. You get higher magnifications – good for viewing detail on the planets, for instance – with telescopes that have longer focal lengths. The downside to this is that longer focal

lengths mean smaller fields of view, which are not always best for observing wide star fields or star hopping. You can, however, increase a telescope's focal length by using an accessory known as a Barlow lens.

Eyepieces also have focal lengths, but since they take the focused light and magnify the image into your eye, the numbers mean the reverse. So the smaller an eyepiece's focal length, the higher its magnification. For example, an 8mm focal length eyepiece will give you a 'closer' view than a 20mm eyepiece.

FOCAL POINT

3. VISUAL VS PHOTO

Your telescope's f/number will tell you if it is particularly suited to observations with just the eye, or whether it will be good for astrophotography too.

Smaller focal ratio (fast) telescopes are good for astrophotography – especially if you want to image large star fields – because they can get an image with shorter exposure times than their long focal ratio counterparts. There's also less chance of stars blurring as a result of your mount's tracking falling behind the movement of the night sky. If you're intending to

mostly use your telescope for visual observing, then larger focal ratio (slow) instruments are ideal. To get 100x magnification with a small focal ratio (fast) telescope, you'd need a small focal length eyepiece that can be uncomfortable to look through, especially if you have to wear glasses. Opting for a slower scope removes this problem. To get the same 100x magnification with a slower, large focal ratio scope you'd use a longer focal length eyepiece, which has longer and more comfortable eye relief.

2. FOCAL RATIO

The focal ratio of any telescope is its focal length divided by the diameter of the front lens or mirror. This leads to another way of describing it – the f/number. Let's say you end up with a '6' once you've done the calculation. The resulting focal ratio would be written as 'f/6'. A scope with an f/number lower than six is said to have a small focal ratio. F/numbers of nine or above are considered large. Knowing your focal ratio is important for astro imaging.

There's yet another way of describing a scope's focal ratio, as fast or slow, a throwback to the days when cameras used film. Small focal ratios meant the aperture of a camera's lens was open wide, which let in a lot of light and caused a 'fast' reaction between the chemicals on the film and the light. The opposite happened with large focal ratios: the narrower apertures in the lens let in less light, causing a 'slow' reaction with the light in the chemicals on the film.

LIGHT PATH

F/NUMBER PROS & CONS

This general guide compares fast and slow focal ratios, and applies to most (but not all) telescopes

FAST	SLOW
Smaller focal ratio: f/4 and below	Larger focal ratio: f/9 and above
Shorter focal lengths: shorter telescope	Longer focal lengths: longer telescope
Wide field of view: good for observing large swathes of the night sky	Narrow field of view: good for zooming in on planets or viewing double stars
Smaller eyepiece eye relief: have to use lower magnifications or viewing can be uncomfortable	Larger eyepiece eye relief: can use higher magnifications more comfortably
Smaller depth of focus: precise focusing required for a crisp image	Greater depth of focus: more tolerance in focusing on objects
Telescopes can be smaller and easier to transport	Telescopes may be larger and heavier and so not as portable

THE BEST OF BOTH WORLDS

Choosing a telescope is not simply about deciding on the best focal ratio. It may be that portability overrides everything; many scopes languish in sheds and garages because they are too heavy or awkward to

move. However, knowing the limitations of fast and slow telescopes is a useful addition to the buying process. If you want to hedge your bets, then it's best to go for the area between fast and slow scopes.

KNOW YOUR FIELD OF VIEW

Different equipment will show you different portions of the sky, but what's best for your chosen target?

When you're out stargazing, the field of view is the amount of sky that you can see at any one time. It varies depending on what equipment you're using – here we show you how the appearance of the constellation of Cassiopeia changes when you look through different types of instrument.



THE NAKED EYE

Your eyes are excellent for expansive views of the constellations, asterisms, meteor showers, the Milky Way and bright comets. Of course, you can see other objects, but it's the general majesty of the heavens that you get with such an amazing, near-180° left-to-right field of view. It makes the naked eye an enjoyable means of looking at the night sky. The main image here shows what the constellation of Cassiopeia, with its easily recognisable W shape, looks like to the naked eye.

It's said that the eye has a magnification of 1x and the faintest stars you can see are mag. +6.5. Some people have claimed to be able to see stars as dim as mag. +7.0; even if you can, you'll still miss nearly all of the wondrous deep-sky objects and any hint of their structure. For these objects you need a pair of binoculars or a telescope.



BINOCULARS

Using a standard pair of 10x50 binoculars you instantly increase your magnification to 10x, meaning things look 10 times bigger. Also, instead of the standard 5-7mm width of your pupils, you have the binoculars' 50mm-diameter lenses to collect starlight. This allows you to see faint stars deep into mag. +10.0 territory.

Depending on the make, 10x50 binoculars have a field of view between 5° and 9°. This gives you lovely wide views to sweep across the sky in search of objects such as nebulae, galaxies and star clusters, which look great through binoculars.

Just outside Cassiopeia there's something well worth viewing with binoculars, the Double Cluster in the neighbouring constellation Perseus. With the naked eye, you can just make it out as a faint smudge. Binoculars, though, reveal it as a true marvel: hundreds of stars in two distinct clusters spanning an area about 1° across. It's a stunning sight that easily fits into the field of view of a pair of 10x50 binoculars.



The Double Cluster looks great through binoculars

9°



LARGE TELESCOPE

Bigger telescopes work with higher magnifications and narrow the fields of view further still, a result of their wider aperture. If you were to take a look at Cassiopeia using an 8-inch Dobsonian fitted with a 12mm Plössl lens, you would be looking with a magnification of over 100x that of your eye at an angular field of 0.5° .

Our target is the open cluster called M52. Viewed through binoculars, this object is simply a faint fuzzy patch. A small telescope begins to resolve the individual stars and shows its roundish appearance. However, a big Dobsonian reveals a fine group of about 200 stars with a diameter of about 0.25° , which fits easily into the field of view. M52 sits within the Milky Way, so the surrounding sky is full of stars and other treasures to investigate.

The large aperture of a Dobsonian scope means that you can see stars and other objects as faint as mag. +14.0. Dobsonians, though, are not built to track (follow) the sky. They point at the same fixed spot. This means that you'll see stars move across the sky as you look through the eyepiece. If your eyepiece increases the magnification to a powerful 400x, the stars will move across your field of view very fast indeed.



Enjoy the full majesty of M52 with a large telescope

The W shape of the constellation of Cassiopeia as it appears to the naked eye

0.5°

1.3°



SMALL TELESCOPE

To see more detail than you get from binoculars you need a higher magnification and an instrument that captures more light. Welcome to the realm of the telescope.

Even with a small scope, like a 4-inch refractor fitted with a 26mm Plössl lens, you'll get a magnification of almost 40x greater than the eye. However, this comes at the cost of a reduced angular field of view, which goes down to about 1.3° .

This kind of setup is useful for taking a look at double stars. Cassiopeia provides

a good example of this with mag. +7.4 Achird (Eta (η) Cassiopeiae), a red star with a brighter, mag. +3.0 yellow companion – though some people say the colours in this double are more golden and purple.

A small telescope will reveal objects well into the 12th magnitude and, because of its enhanced light-gathering power, things like the shapes of nebulae and detail on planets become apparent. Plus, for the first time in our equipment choices, you have the option to increase the magnification further by changing eyepieces.

You can split the beautiful double star Achird with a small scope



KNOW YOUR TELESCOPE MOUNTS

The basic types explained, plus what to consider when buying



CAMERA TRACKING MOUNT

These recently developed mounts attach to a standard tripod and the hinge is angled towards the celestial pole, allowing for tracking with a camera so long as a polar alignment is performed during set up. Many can even support small telescopes, making them useful if you want to travel.

Try holding even a small telescope for any length of time and it will quickly become apparent that you need something to support it – this vital piece of any setup is the mount. There are several types, and which one is best for you, and indeed how much you'll have to pay for it, depends on what you want to use your telescope for. The mounts

available to today's amateur astronomers suit a range of needs, from a simple tripod right up to a sophisticated instrument fit for an observatory.

Most mounts are a variant of two basic designs, altazimuth (altaz) and equatorial. Altaz mounts move in two axes, one perpendicular to the horizon (altitude, giving an up and down motion)



ALTAZ MOUNT

The simplest form of altaz mount is the humble tripod, which is easily portable and comes in styles from lightweight models to sturdy affairs that are more than capable of holding a small refractor or small compound telescope. Dual-mounting manually operated altaz tripod mounts are also available.



GERMAN EQUATORIAL MOUNT

A popular mount design that allows for the tracking of the stars as Earth turns by having one axis parallel to our planet's rotational axis. With a variety of carrying capacities – from non-motorised mounts up heavy-duty tracking systems suitable for an observatory, this is the mount of choice for many.

and the other parallel to the ground (azimuth, giving horizontal motion), but most basic designs cannot track the sky – though there are a few exceptions to this.

In equatorial mounts, one of the axes is parallel to that of Earth's rotation, meaning they can track the night sky and keep targets centred in the field of view, provided they are properly polar aligned prior to use. This makes them ideal for prolonged observing or for long-exposure astrophotography.

There are other considerations to take into account. If you want a permanent setup, then a heavy-duty mount with excellent tracking would be ideal. Being portable and easy to set up may be a more practical solution for some, perhaps where space is limited, so a lightweight but robust mount could be a better choice.

Weight and see

Similarly, you need to consider the mount's payload capacity – in other words, how much weight can it support? Remember, if you want to do any astrophotography, this weight has to account for all of your kit, not just the telescope. Can the mount-telescope system be easily dismantled if the clouds roll in or, conversely, set up quickly if a patch of clear sky appears? If you're thinking of a computerised mount, you need to check to see if it has the relevant ports for any accessories you might want to use.

Choosing a mount can be a daunting thing; there are a lot of options. But it is also true that there is a suitable mount for all occasions. With a little consideration you should be able to choose the right one for your needs.



DOBSONIAN MOUNT

Devised by renowned amateur John Dobson, the Dobsonian is a simple rocker box on a turntable made from basic materials that supports a large Newtonian reflector. The design is an easy to use, manually operated altaz system, although there are now some computerised models that can track the sky.



FORK MOUNT

Typically altaz, though they can be converted to equatorial using an equatorial wedge. Motorised or computerised fork mounts can move the telescope through the southern meridian without a meridian flip, allowing for imaging sessions across the meridian, which is a problem for German equatorial mounts.

GRAB AND GO-TO

Go-To is a computerised setup involving a handset with the ability to smoothly control the mount and point it at a huge database of celestial objects once an initial star alignment routine has been performed. Go-To systems take the hassle out of manually trying

to find an object, especially if they are faint, and can do away with using printed star charts. Their databases usually include the Messier and NGC catalogues, and the major planetary bodies. This opens up the sky to novices and allows

experienced astronomers to quickly locate and track deep-sky objects for astrophotography. These days, Go-To technology is available on German equatorial and fork mounts both large and small, and can even be found on some altaz systems, including Dobsonians.



EQUATORIAL MOUNTS

PART 1 SETTING UP

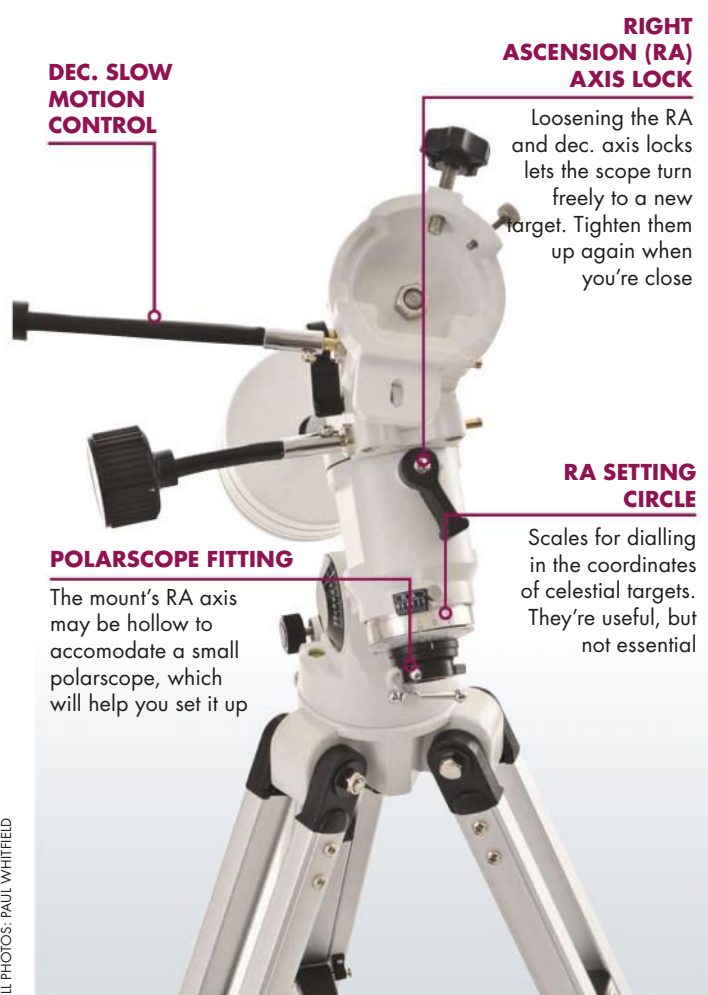
Equatorial mounts let you track an object as it moves across the night sky

Putting your telescope on an equatorial mount enables you to follow stars as they continue their steady progress across the night sky. The mount may look complex, but it really doesn't take long to master.

Over the next six pages, we're breaking down everything about these mounts into easy-to-follow steps, starting with putting them together. We're using an EQ3 mount, but the techniques will work for other types, too.

MOUNT HEAD

An equatorial mount is made up of a tripod and a mount head, which holds the telescope and moves it about on two axes, one called right ascension (RA) and the other called declination (dec.)



TUBE RINGS

These go round the telescope to fix it to the plate, which fixes to the mount head

RA SLOW MOTION CONTROL

With the axis locks tightened, this is used to fine-tune exactly where the scope is pointing

AZIMUTH LOCK

Moves the mount parallel to the horizon for setting it up. Not used to find targets

COUNTERWEIGHTS

These balance the weight of the scope

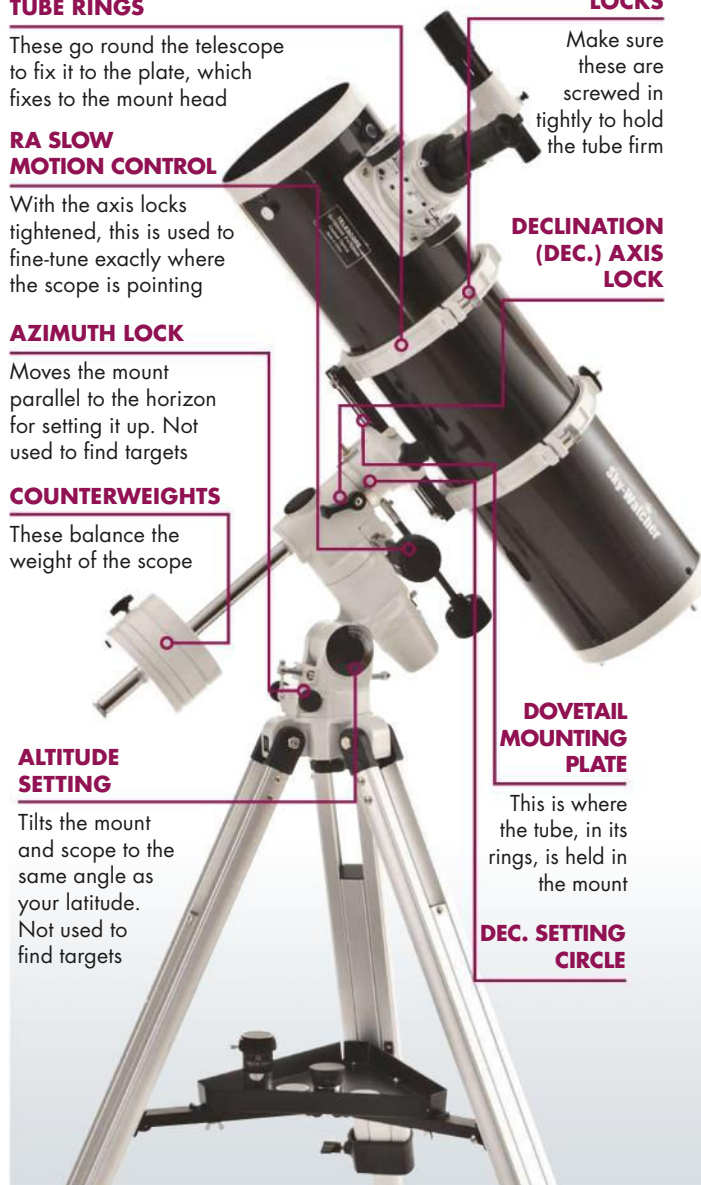
ALTITUDE SETTING

Tilts the mount and scope to the same angle as your latitude. Not used to find targets

TUBE RING LOCKS

Make sure these are screwed in tightly to hold the tube firm

DECLINATION (DEC.) AXIS LOCK



HOW TO ASSEMBLE YOUR MOUNT

Follow these steps to make sure your equatorial mount is solidly built and won't collapse when you fit your telescope onto it



1. The scope and mount head sit on a **TRIPOD**. Set this up in daylight if it's your first time. Adjust the height of the tripod's legs so the top is level with your hips and, if there is one, fit the central accessory tray. Make sure that the top is level and that the leg labelled 'N' is pointing north.



2. Place the **MOUNT HEAD** onto the top of the tripod. Line up the metal peg on the top of the tripod with the gap underneath the mount, between the azimuth lock's two bolts. Secure the mount head onto the tripod by tightening the big bolt hanging from the underside of the tripod top.



3. Screw the **COUNTERWEIGHT** bar into the mount head. With the rod's locknut tightened against the mount, take the safety screw off the end of the bar and slide the counterweights halfway up the bar, tightening the screws on the weights to secure them. Then replace the safety screw on the end.



4. The RA axis needs to point up to the north celestial pole. To do this, the mount's **ALTITUDE SETTING** needs to be the same as your local latitude. Release the front and back bolts and tilt the mount head so that the pointer lines up with the right number on the altitude scale, then do the bolts up again.



5. Fit a **SLOW MOTION CABLE** onto the small D-shaped shafts on the RA and the dec. axes, tightening the screw at the end of each cable to hold it in place. If using a refractor, rotate the dec. axis so that the cable extends to the bottom. For a reflector, fix the cable on at the top, closest to the eyepiece.



6. The telescope is held in the mount head by two **TUBE RINGS**, which are attached to a mounting plate clamped tightly into the mount head. Our example has a short dovetail mounting plate with two tube rings already attached, but yours may not be fixed to the mount head. In which case, attach the rings.



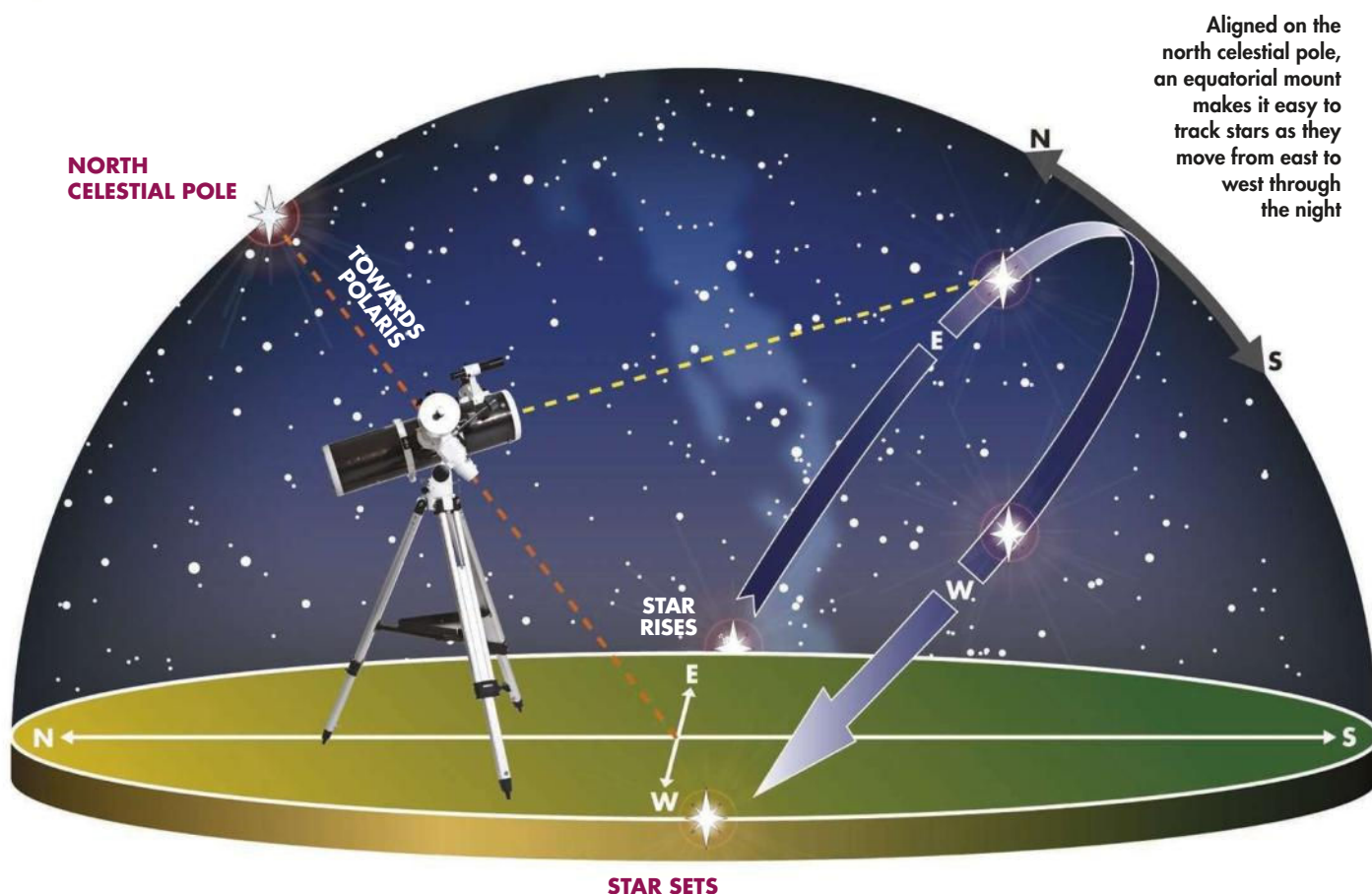
7. With the tube rings open, **PLACE THE TUBE IN THE RINGS**, then flip the top half of the rings over the tube and screw down the locking bolts tightly so the tube doesn't slide out. You might need an extra pair of hands to help you at this point. Remember, if you've got a reflector the eyepiece goes at the top!



8. Slip the **FINDERSCOPE** into its bracket and screw this into the clamp on the telescope tube. To align it, put a low-magnification eyepiece in the main scope's focuser and find a target on the horizon. Look through the finderscope and adjust the screws on its bracket until your target is in its crosshairs.



9. BALANCE YOUR SCOPE. With the tube horizontal and the dec. axis lock loose, slide the tube back and forth in the rings until the scope rests flat. Then do the RA axis: with the counterweight shaft horizontal, loosen the lock and adjust the counterweights until the scope stays put when you let go.



EQUATORIAL MOUNTS

PART 2 ALIGNING

The second part of our guide to equatorial mounts shows you how to align one so that it can track the stars

In Part 1, we looked at setting up an equatorial mount so it would be a solid and stable platform for holding your telescope. Now we're going to explain how to make the mount follow, or track, stars and other objects as they move with the sky as the night hours tick by.

To do this properly, the equatorial mount has to be 'polar aligned' – that is its right ascension (RA) or polar axis must be lined up so that it points at the

north celestial pole. This is the point that the sky appears to rotate around. It's a notional spot that denotes the point at which our planet's axis of rotation meets celestial sphere, that imaginary ball with the Earth at its centre, onto whose inner surface all the stars are projected. The sky, in fact, only appears to rotate; it's actually Earth that's rotating, once every 24 hours. But since we're observing from

the surface of the spinning Earth, it looks as though it's the night sky that is rotating around us.

Pole position

Since the sky rotates (or appears to) around the north celestial pole, the mount also has to be aligned to this axis of rotation to track the stars' movement. Equatorial mounts are designed specifically to be polar aligned

ALIGNMENT TIME

Four steps to lining up on the north celestial pole



1. Adjust the mount's altitude setting so that it's the same as your local latitude. In the UK, this will be between 58°N (John O'Groats) and 50°N (Land's End). Release the front and back bolts and tilt the mount head so the pointer lines up with the right number on the altitude scale, then do the bolts up again. Doing this aligns the mount's right ascension (RA) or polar axis with Earth's axis of rotation, so that the two are parallel.



2. As well as being angled up, the polar axis needs to be aimed so its highest end points due north. Some mounts have a big 'N' at the top of the tripod to show which side should face north. You can use a compass to find out which direction is north, but remember that this will show magnetic north and we want true north, which is a few degrees east. At night, find the star Polaris and line up the polar axis with it.



3. The mount should now be polar aligned. To check that it is, when the stars are out look along the polar axis up at the sky and make sure that it is pointing at the star Polaris. This kind of visual alignment is fine for making observations through the eyepiece. But for more accuracy – if you want to take photos through your scope, for instance – you'll need to polar align looking up through a polarscope fitted in the RA axis.

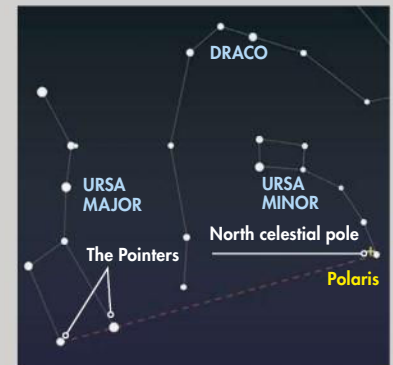


4. If you need to make any fine adjustments to get the polar axis aimed at the north celestial pole, use the altitude and azimuth settings. Make altitude adjustments like those covered in Step 1. To make azimuth adjustments, unscrew the two azimuth bolts to move the mount head and scope left or right slightly, parallel to the horizon. This is easier than lifting the tripod and the whole setup to aim the scope due north.

THE POLE STAR

In the northern hemisphere, we're lucky enough to have a fairly bright star sitting practically at the point that the sky appears to rotate around: the north celestial pole. This star is Polaris, the Pole Star, in Ursa Minor. Find it and you'll have found true north. What's more, it never shifts from that position during the night while everything else in the sky turns around it.

Polaris is actually 0.7° away from the north celestial pole. This tiny offset doesn't matter for visual observations, but to take astro images you'll need more accuracy: polar aligning through a polarscope takes that 0.7° offset into account. Polaris is easy to find, courtesy of two stars in Ursa Major known as the Pointers. Simply draw a line through them and you'll end up at Polaris, as shown below.



Find Polaris by drawing a line to it through the two stars in Ursa Major known as the Pointers

– if you don't bother, you might as well have saved your money and bought a cheaper altazimuth mount.

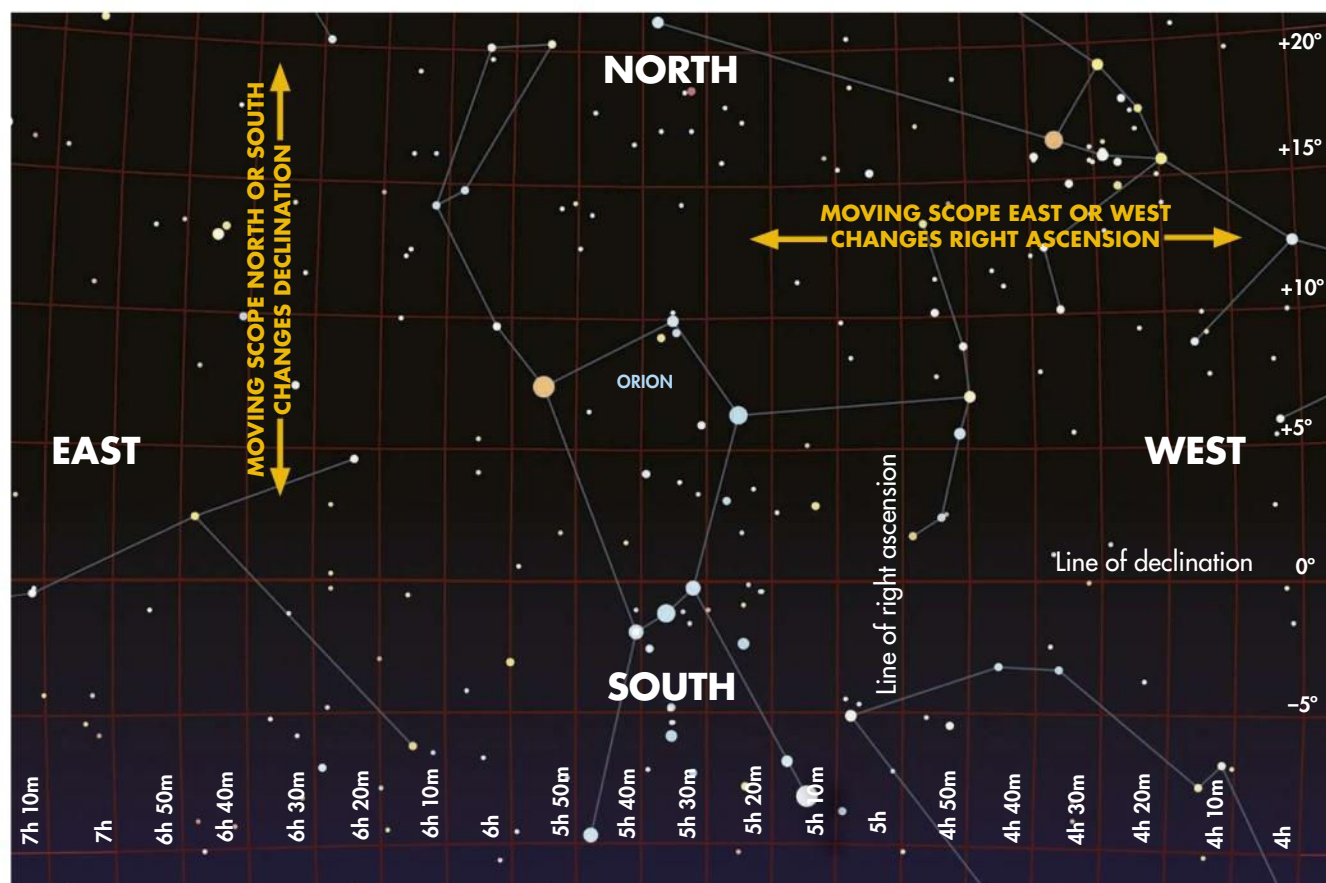
When it comes to getting your mount's polar axis pointing in the right direction, those of us in the northern hemisphere have a helping hand because the bright star Polaris sits very close to the celestial pole. This provides an instant 'marker' – and the good news is that, for visual observations, you don't need to be overly

accurate in your polar alignment. Simply adjust the altitude setting so it's the same as your local latitude (find this at <http://itouchmap.com/latlong.html>), then pointing the polar axis north so it's lined up on Polaris. If you're intending to do any astrophotography you'll need to be more accurate, and you should polar align using the mount's polarscope.

Once the mount has been lined up on the celestial pole, your scope will track

the stars with ease and you'll find it simple to keep objects in your eyepiece for longer. You only need to adjust the RA or polar axis with its slow-motion control to do this. It's unlike a camera-type altazimuth mount, which needs its two axes to be adjusted to track objects. But remember that even an equatorial mount will need both its axes adjusted when you want to move the scope so that it points at another star.

EQUATORIAL MOUNTS



Declination can be thought of as latitude, and right ascension as longitude, in a sky-wide system of co-ordinates that can pinpoint any object

PART 3 HOW THE MOUNT MOVES

How to move an equatorial mount's axes to keep you on target

In the first two parts of this guide to equatorial amounts, we've looked at how to set up your mount so that it will do its job properly, making it easy to find and follow objects out there in space. A star, planet or nebula can be found by using its co-ordinates on the great imaginary sphere projected onto the night sky, with the Earth at its centre – the celestial sphere.

As we mentioned previously, finding a galaxy in this way is almost identical to the way you locate places on Earth using

latitude and longitude; you just imagine the grid projected onto the starry realm. The only difference is that on the celestial sphere, latitude is known as declination (or dec. for short) and longitude is known as right ascension (or simply RA).

Both of these systems work in exactly the same way as they do for locations on Earth. Declination (latitude) lines run parallel to the equator from east to west, while right ascension (longitude) lines run 'up and down', from north to south. Every single object in the night

sky has dec. and RA co-ordinates, just as every location on earth has a latitude and a longitude. By using the dec. and RA setting circles on your equatorial mount, you can point your scope to find anything in the sky with just these two figures.

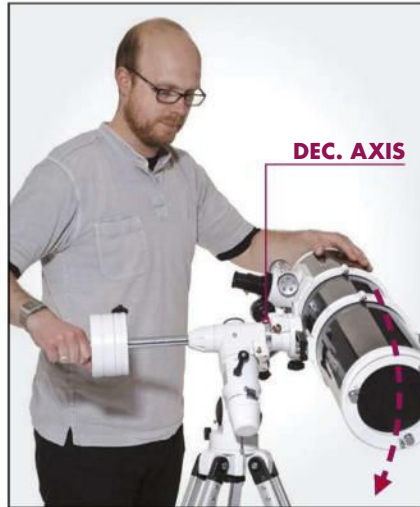
Assuming you've already polar-aligned your scope as detailed in Part 2, the first step to finding that galaxy is to make sure your right ascension setting circle is set correctly. For this you'll need the RA co-ordinates of an easily found bright

WHEN THE TUBE BUMPS THE TRIPOD

To keep track of your quarry as it moves from east to west, you might need to do a 'meridian flip' – here's how to perform this manoeuvre in three steps



1. If your telescope's tube bumps into the tripod as you're tracking an object moving with the night sky, rotate the telescope tube by 180° in right ascension.



2. Next, rotate the declination axis so that the telescope tube is pointing at the object again. You can use the declination axis setting circle to get back to the original spot.



3. You're ready to begin observing again. A meridian flip is often needed on objects that are at their highest in the sky, so the tube is pointing straight up.

star, like Vega in the constellation of Lyra. Vega's co-ordinates can be found from a star atlas, or a planetarium program such as Stellarium.

Head for Vega

Loosen the locks on both the RA and Dec. axes and move the scope until it is more or less visually aligned with the star, then use the slow-motion controls – and your finderscope – to zero in on the target.

Now take a look at the RA setting circle dial. If this is your first setup, it might not be reading the exact RA position that you looked up earlier. If

this is the case, don't worry: simply rotate the RA setting circle's dial until the pointer reads the correct co-ordinate. The dec. setting circle's dial is fixed in position, so you needn't fret about this going out of alignment. Now you can use the setting circles to find your star, simply by moving the axes so that the setting circles match the galaxy's dec. and RA co-ordinates. You can use this method to locate objects that are below naked eye visibility, too.

The beauty of the equatorial mount now comes into play: as you gaze in wonderment at your star, you only need to adjust the RA axis with its slow-

motion control to keep it in your eyepiece as it moves from east to west across the sky. And if you find the occasional twiddling of the RA slow-motion control a little tedious, you can get a motor to attach to this axis, which will do the tracking for you automatically.

As for the declination axis, you don't have to touch that or its slow-motion control until you want to look at a different object. Then you just look up the co-ordinates of your next quarry, and move the dec. axis and the RA axis until the setting circle dials give the right readings.

So, a well-handled equatorial mount is pretty much the perfect solution to hassle-free stargazing. Well, almost; there is one thing it can't do, and that's track an object all the way across the sky. There will come a point when the bottom of the scope's tube will bump into the tripod leg, especially if it's a long tube. Luckily, there's an easy trick to get around this called a 'meridian flip' – see above.

Hopefully, if you've read all three parts of this guide, you've now got a bit more confidence when it comes to using an equatorial mount. Astronomers have been fixing their telescopes on this kind of mount for almost two centuries; now you can too.



Adjusting the declination axis moves your telescope in a north-south direction



Adjusting the right ascension axis moves your telescope in an east-west direction

GO-TO TELESCOPES

Locate celestial objects at the push of a button with our guide to using a Go-To telescope

To get an idea of just how much modern technology has influenced astronomical observing, take a look at the Go-To scope. A Go-To is basically an ordinary telescope, but added to its mount are motors and a digital map of the night sky containing tens of thousands of astronomical objects. All this is stored in computer circuitry within the mount and it's this, rather than the scope itself, that is really the 'Go-To' part of the system.

Once the Go-To has been correctly set up, you simply choose a celestial object that you want to view by using the buttons on the handset. It's at this point the motors kick in and the whole mechanism whirs and turns around, 'going to' the object you've chosen, which will eventually appear in the eyepiece. Sounds pretty straightforward, don't you think?

Certainly, but there's a reason why Go-To telescopes come with such a substantial manual. Before you can get to the impressive stage of being driven around the sky to objects you've selected, you first need to have your Go-To scope set up correctly. Using a Go-To is not the straight-out-of-the-box method of stargazing it might at first appear.

Setting up

There are a few things you need to know in order to get a Go-To scope working. Firstly, not every scope has the same setup routine, nor are these routines all as easy to perform as each other. When deciding on a Go-To scope, you should do plenty of research to avoid buying one that you'll never use because it's too complicated.

There's some basic information that the Go-To computer needs to know when you're setting it up: your location, the date and the time. With these details keyed in to the Go-To, the telescope can

AN EQUATORIAL GO-TO SCOPE

GO-TO MOUNT AND DRIVE

The nerve centre of a Go-To system includes a digital map of the night sky

POWER

The mounts on equatorial Go-Tos need an external power source. Altaz Go-To mounts often take batteries

HANDSET

You key in destination details here. The buttons and readout should be illuminated in red to preserve night vision

TRIPOD

The tripod needs to be sturdy and level to ensure the Go-To's readings are accurate

CABLE

Be careful that the cable doesn't catch in the mechanics, particularly on an equatorial mount



LATITUDE AND LONGITUDE



Some Go-To scopes sit on altaz mounts

If you live in a small town or a rural environment, the computer database in the Go-To handset may not have location details for your area. In this case you'll need to supply the co-ordinates of your latitude and longitude. There are plenty of websites that make it easy to discover these location details. They often feature a world map so you can zoom in and click on your location to find your co-ordinates.

You may need to convert the latitude and longitude of your location from the decimal version into hours, minutes and seconds. A search online for 'latitude longitude conversion' will bring up myriad sites that will do this.

Only use the minus sign for latitude if you are south of the equator, as it means the southern hemisphere. For longitude, minus means that the location is west of the Greenwich Meridian, pictured right, so this includes all of western Britain, North and South America. Parts of

Britain east of Greenwich, and all of Europe and Australia, have a positive longitude, but don't need a plus sign.



The Greenwich Meridian marks 0° longitude

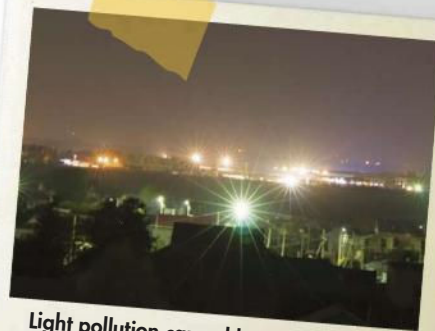
correctly orientate the star charts in its memory. Some Go-To scopes come with a GPS receiver built-in that helps with this initialisation procedure.

Now you're ready for alignment. Firstly, make sure the tripod and telescope are level. If there's any sloping ground you haven't compensated for, the scope will miss its target object. This is especially true for a Go-To on an equatorial mount. With scopes like these, you should polar align the mount first. The Go-To system will then ask you to centre several alignment stars in the eyepiece. When you've done this, you're ready to go.

Other Go-To scopes are mounted on an altazimuth mount – either a single-arm or fork type. With an altaz mount, you will need to centre one or two alignment stars in the view. With either equatorial or altaz Go-Tos, the more stars you align on, the more accurate the mount will be. This is a consideration that becomes particularly important if you're planning to do any astrophotography.

Finally, remember that there's one essential link in this high-tech chain of technology – batteries. Always carry spares, or consider buying a powerpack to ensure you don't run out of power while observing.

THE PROS & CONS



Light pollution caused by artificial lighting can make it hard to see the stars

PROS

- In light-polluted skies, it's easier to locate objects that you wouldn't otherwise be able to find if you were manually star hopping when the stars might be washed out.
- Go-Tos are good for taking photos that are free of star trails, as the scope will track the movement of the night sky.
- If you're planning to show friends several objects in the night sky, a Go-To is fast and efficient.
- A Go-To database can be updated when new comets or supernovae are discovered, so you can find new objects quickly and easily.

CONS

- The database may contain tens of thousands of objects, but how many you can see will also depend on the scope's optics and seeing conditions.
- You need to ensure the battery has enough charge for the observing session – once a Go-To scope has lost its power there is no way to use it manually.
- By not manually scanning the heavens, and with the scope doing all the locating, you may miss chance encounters with intriguing objects.
- You need to set up and align a Go-To correctly each time you head out to observe, in order for it to accurately locate objects. This takes time.



Dark sites rarely have sockets, so keep an eye on your batteries: flat scopes don't track

CHOOSING ACCESSORIES

How to make smart choices when it comes to astronomy add-ons

Eyepieces and filters are good early investments; they can make a huge difference to your observing experience



We've all heard it before: "The telescope is the important bit, right?" To some people, it is the thing that makes you an astronomer and is, as far as they are concerned, the be all and end all when it comes to stargazing. They are, of course, quite wrong.

A telescope tube is nothing without a suitable mount, tripod and eyepiece at the very least, and this is just the tip of the burgeoning world of astronomical

accessories. Sometimes dismissed as 'just extras', they are often the important finishing touches that make stargazing enjoyable and fulfilling.

Here's the thing: there are hundreds of accessories available. Once you're comfortable with your basic setup – and we'll assume you're happy with your mount and tripod – what do you add next? Do you need to invest in anything at all?

A good place to start is with the most essential accessories of them all – your eyepieces. Most telescopes are supplied with one or two, but that is no guarantee of their suitability or their quality. Your eyepieces are as important as your telescope's main mirror or lens, as they take the light gathered by the scope and magnify it for your eye. Poor eyepiece optics could introduce aberrations that deteriorate the view; if you wear glasses,



Dew shields come into their own on cold nights, while power packs offer extra portability

you may want to buy an eyepiece with particularly long eye relief to make observing more comfortable.

Beyond the essential

You should pay the same heed to the other accessories often bundled with new telescopes: finderscopes, Barlow lenses and (with refractors and compound scopes) star diagonals. But beyond these essential items, what you add to your astronomy toolkit entirely depends on what you want to achieve.

Filters can help you see more detail in night-sky objects, but you'll need different ones depending on whether you want to pick out the polar caps on Mars or the faintest regions of emission nebulae. If you live in an urban area that has a lot of street lighting you may find that a light pollution filter becomes a greater priority than either, regardless of what you want to see.

If you regularly take your scope to a dark-sky observing site, on the other hand, a strong carry case to get it there

and back in one piece may prove more useful. Likewise, portable power packs for computerised mounts might be optional if you can simply run an extension cable from your kitchen, but they become invaluable when you are away from home.

Embarrassment of riches

If your interest extends to imaging then there is an even wider range of accessories to consider. In addition to a camera and an adaptor to connect it to your scope, there are filter wheels to help you switch filters speedily, autoguiders to help keep your target centred during long imaging sessions and dew heaters to keep the view fog free. These are just a few examples.

Remember that 'accessories' don't have to attach to the telescope itself. Star charts, guide books and even smartphone apps are invaluable if you want to start star hopping around the night sky with aplomb – and you'll be hard pressed to protect your night vision while reading them without a red light torch. Apps have an added benefit if you want to travel abroad, in that they weigh nothing and, in some cases, can be set to match the sky over your location.

Astronomers love to accessorise and it could be said that for every star in our Galaxy there is an appropriate astronomical add on. However, what this should serve to illustrate is that accessories are a vital part of your toolkit, and picking the ones that are right for you, your setup and your stargazing goals is worth some careful thought if you want the best experience.

Just a few of the useful extras for the budding astronomer. Left to right: a dew heater, filter wheel, red light torch and smartphone app



INTRODUCTION TO EYEPIECES

Eyepieces may be small, but they play a big role when it comes to ensuring you get the most from your observing sessions

The importance of eyepieces can take a long time to realise. To say they can make or break you as an amateur astronomer may be going a little too far, but certainly when you look through a good eyepiece for the first time you realise that what you've been observing for all those years could have looked much clearer. It all comes down to experience. Some astronomers are glad they went through the years of wrestling with low-quality eyepieces, as it gives them an appreciation of what it takes to see the night sky properly.

Small refracting telescopes sold at a reasonable price are frequently packaged with a metal tripod, a basic altazimuth mount, a finder, a couple of eyepieces and a Barlow lens that will double their magnification.

The mount often comes with an eyepiece tray that sits between the tripod legs and holds the Barlow lens – always a useful feature when observing. As all eyepieces are a slightly different length depending on their power, it becomes quite easy to feel which was which in the dark when you want to change the view. And their owners carry out many, many happy observing sessions with that first telescope and its eyepieces.

Like most that come with small refractors, or indeed reflectors, the eyepieces are not of the greatest quality, but get the job done, especially if you put them back into their little boxes after every observing session and make sure they stay scrupulously clean. The last thing you want to do with these seemingly insignificant, yet important,



JARGON BUSTER

EXIT PUPIL This is the size of the image that comes out of the eyepiece. Ideally it should be close to the size of your dark-adapted pupil – around 5mm to 7mm.

EYE RELIEF This tells you how far your eye must be from the eyepiece in order to see the entire field of view. A bigger distance (called longer eye relief) is useful if you wear glasses.

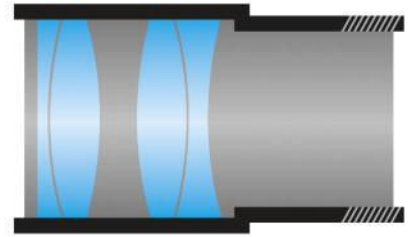
FIELD OF VIEW This is sometimes abbreviated to FOV, and

is the figure that lets you know how much of the sky you can see through your eyepiece. This measurement is given in degrees.

POWER This is just another name for magnification. A telescope just captures the light – it is the eyepiece that magnifies the image.

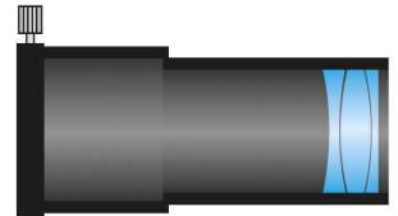


HOW AN EYEPIECE WORKS



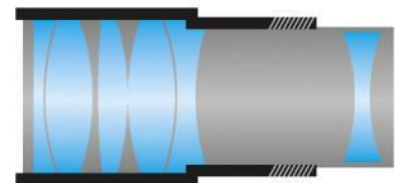
PLÖSSL EYEPIECE

Of the 25 or so types of eyepiece around, this is the one you will mostly hear about as it's the most common. The internal construction of two back-to-back convex and concave lenses, and the quality needed for the lens elements, makes them fairly costly to make and buy. Plössls benefit from a wide field of view (around 52°), but eye relief can be a bit short if the lens has a focal length of 12mm or less.



BARLOW LENS

This is not so much an eyepiece, but an eyepiece's friend. A Barlow lens intercepts the light from the telescope before giving it to an eyepiece. What this lens does is double or triple the magnification you would otherwise get from just an eyepiece alone. So, buy your eyepieces carefully and let a single well-made Barlow effectively double the number of eyepieces, and therefore powers, you have.



ULTRA-WIDE ANGLE

As the name suggests, this provides you with an ultra-wide 82° or so field of view, which is just gigantic. There is also 'super-wide' variants with around 67° fields of view, but the scene through an ultra is something else. If you took one apart (though this is certainly not recommended) you would find six or seven elements, all coated to provide you with the best light-gathering possible.

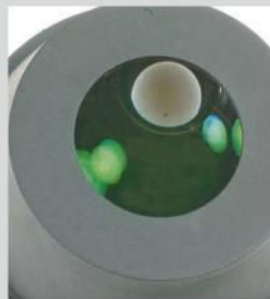


An eyepiece sits in a telescope's focuser, held there tightly by a little screw

COATINGS

As light passes through the lenses in your eyepiece, a little bit of it is taken away. To minimise this loss of light, manufacturers coat the lenses with substances like magnesium or calcium fluoride. The best eyepieces will be the ones that say they are 'fully multi-coated', though 'multi-coated'

eyepieces are still good. Try to avoid eyepieces that are described as 'fully coated' or just 'coated'. One way to test the coatings is to fix a black cap on the bottom of your eyepiece and look down the barrel in daylight. The darker the glass looks, the less light is lost and the better the eyepiece.



things that you pop into the end of your telescope is to get them scratched or damaged. Failing to do this means you'll have to replace them sooner, yet this could mean realising earlier how much you have been missing!

An eyepiece is just as important as the scope's main lens or mirror. It takes the light that's captured and focused by the scope and magnifies the image that goes into your eye. It sounds simple, but the eyepiece needs to do this effectively if you're to get a really good view.

Cost and quality

Another reason to keep your eyepieces in the best possible condition – and possibly one reason why they are not always a major consideration when you're buying observing equipment – is the cost of replacing them. The better little cylindrical eyepieces are

manufactured to an exceptionally high standard. Some have multiple glass lenses inside that fit together to give you a beautifully crafted accessory that will last and last. You can pay anything from around £30 up to £400 for a good eyepiece – and an item with that kind of price tag is something you'll definitely want to look after.

The diameter of an eyepiece gives some indication of how well it's built. If the barrel measures just under an inch in diameter (and most eyepieces are described in imperial units) then it's most likely been given away with one of the cheaper telescopes. But in truth, neither the telescope nor the eyepiece will be with you for the long-term. Most decent telescopes for beginners have a 1.25-inch eyepiece barrel; when you get up to the really good, and expensive, stuff, though, it's two-inch barrels all the way.

CHOOSING AN EYEPIECE

Make sure you get the best view of the night sky by using the right eyepiece

Which is more important: the telescope or the eyepiece? The telescope gets lots of attention because it's the most expensive and impressive-looking part of your setup – but without decent eyepieces, the views you get can be disappointing.

What you ideally want is a good range of eyepieces, because different focal lengths are useful for producing better views of different kinds of objects. This is due to the fact that each eyepiece will have a differing field of view and magnification, depending on the telescope used.

Size matters

To find out what magnification you're getting with any eyepiece takes a very easy calculation – you simply divide the focal length of the telescope, which is usually printed on a label on the scope near the eyepiece end, by the focal length of the eyepiece. The focal length of any decent eyepiece will be marked in millimetres around its collar. So for example, to work out the magnification of an 800mm focal length telescope with a standard 25mm focal length eyepiece, you divide 800 by 25, which is 32. This setup will magnify objects you see in the eyepiece by a factor of 32.

For wider views of nebulae and star clusters, this is the kind of number you will want. With higher magnifications, maybe with a 10mm

eyepiece, you'll get more detailed views of the planets and double stars.

As you progress in astronomy, you will undoubtedly start to experiment with the different views that a range of eyepieces can offer. So make sure you don't underestimate these small, seemingly insignificant bits of astro equipment!

“You want a range of eyepieces, as different focal lengths are useful for producing better views of different kinds of objects”



KNOW YOUR EYEPIECES

There are four main types of eyepiece; a Barlow will increase their magnification

PLÖSSL

Plössl's have a wide field of view (around 52°), so they can be used successfully for planetary as well as deep-sky viewing. The drawback is the short eye relief that becomes an issue with focal lengths of 12mm or less. Eye relief refers to how far your eye must be from the eyepiece in order for you to see the entire field of view.

The internal construction of a Plössl eyepiece consists of two back-to-back lens systems. There's quite a price variation between the highest quality examples and those produced more cheaply.



RADIAN

The Radian is one of the newer types of eyepiece on the market. With a field of view comparable to a Plössl, you may wonder what the difference is? Well, one is the big eye relief – even with focal lengths down to 3mm. This is a lifesaver if you need to wear glasses while observing, and very user-friendly for everyone else. The design suits medium and higher magnifications in order to get plenty of detail when looking at the planets. Internally, there are six or seven lens elements that have very short focal lengths.



NAGLER

The Nagler's most impressive attribute is its huge field of view. While other manufacturers keep their eyepieces within the human eye's 50° field of view, Naglers go the extra mile to develop an ultra-wide 82° field. Imagine the amazing vistas of star fields and nebulae you get with that! The design incorporates six or seven elements, all coated with special chemicals to increase the amount of light that travels through the eyepiece. The downside to some of these eyepieces is their weight, which may require you to rebalance your scope.



ORTHOSCOPIC

These were the mainstay for many an amateur astronomer until the Plössl's took over, but Orthoscopes are still good little eyepieces. They're made with a four-element optical system that provides very good eye relief. The design also keeps down the amount of light that is refracted within the system very effectively. The field of view, at only 40° to 45°, may not be as great as a Plössl, but they are still pretty good all-rounders. They come in particularly useful for making observations of the Moon and planets.



DOUBLE UP WITH A BARLOW LENS

This is a marvellous bit of kit. It isn't actually an eyepiece, but has optical elements that work with an eyepiece to increase the magnification. This is achieved by a very simple process: you basically slot the eyepiece into the Barlow lens and the whole contraption gets popped into where the eyepiece would normally go. Depending on the Barlow, you can double or triple the magnification you would get from the eyepiece alone. This means that with one Barlow lens you have effectively doubled the number of eyepieces – and therefore magnifications – that you have at your disposal.



FIELD OF VIEW

These three diagrams show what field of view (FOV) is all about. Needless to say, the wider the field of view, the more of the sky you can see. The first view of the Moon shown here is that seen using just a 25mm eyepiece. In the next image we take an even closer look, with a narrower field of view, by changing to a 10mm eyepiece. Finally, an even smaller field of view as we use a Barlow lens with the 10mm eyepiece. The FOV is given in degrees (°) and arcminutes (') above each view.

FOV: 2°7'



25mm eyepiece
with a 650mm telescope

FOV: 51'



10mm eyepiece
with a 650mm telescope

FOV: 25'



10mm eyepiece and 2x Barlow
with a 650mm telescope



Filters come in many guises and their effects are just as varied; some can help give you better views of planets, other galaxies and nebulae

UNDERSTANDING FILTERS

These tiny accessories can make a huge difference to what you can see

If there is one seriously neglected and underused tool in your astronomical toolbox, then it surely has to be the filter. These often-colourful discs are available in 1.25-inch or 2-inch sizes and screw into the barrel of an eyepiece, the end that attaches to a telescope. The point of filters is that they alter how astronomical targets appear. They work by stopping – filtering out – some wavelengths of light from passing through your telescope's tube, changing what you see through the eyepiece.

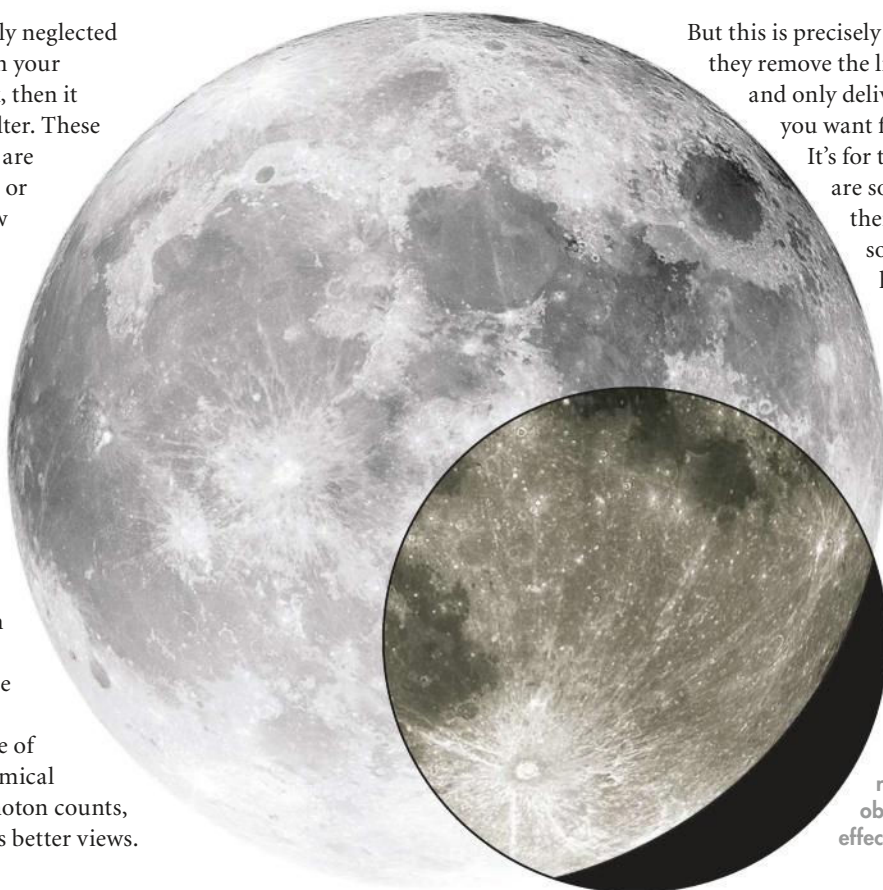
This flies in the face of conventional astronomical wisdom that every photon counts, that more light means better views.

But this is precisely the point of filters: they remove the light you don't need and only deliver the wavelengths you want for a given situation.

It's for this reason that there are so many filters out there. Some are coloured, some are clear, but each has a slightly different effect and is designed with a different purpose in mind.

Sometimes the effects can be remarkable: there are, for instance, filters that can enhance the polar caps of Mars and reveal the subtle shadings of clouds on the otherwise

A neutral density filter reduces glare from bright objects, which has the effect of improving contrast





COLOUR FILTERS

Colour filters are designed for planetary work. They are often referred to by their Wratten number, written in the style '#1'. This is based on the original Eastman Kodak filter range, which had 100 shades, although for most astronomical purposes only a few are required. Among the most useful are:

#8 (Yellow) – For cloud bands on Jupiter and Saturn

#25 (Red) – For picking out surface detail on Mars and cloud details on Venus

#47 Violet – Useful for Venus and enhances the Schröter effect

#58 (Green) – For improving red features such as Jupiter's Great Red Spot

#80A (Blue) – For Martian dust storms and clouds, and the belts of Jupiter



ULTRA-HIGH CONTRAST

Like narrowband filters, ultra-high contrast filters improve contrast, making the background sky darker and helping deep-sky targets to stand out better. They pass both hydrogen-beta and oxygen III light, so will improve your view of a wider range of nebulae than any single narrowband filter.



LIGHT POLLUTION REDUCTION

These are designed to suppress the specific wavelengths giving the orange glow from sodium streetlights, with the result that they darken the background sky. This can help you see deep-sky objects better, particularly nebulae and galaxies, as they are more easily washed out than the planets are.



NARROWBAND

As the name suggests, narrowband filters cut all but a few select wavelengths of light – typically the ones emitted by bright emission and planetary nebulae. By blocking the rest, they help to improve contrast and so bring out subtle detail. Typical narrowband filters include hydrogen-beta and oxygen III.



NEUTRAL DENSITY/ POLARISING

Both of these filter types reduce the glare of bright targets – the Moon, Venus, Mars, Saturn and Jupiter. Neutral density filters reduce the intensity of all wavelengths, but are particularly favoured for lunar use. Polarising filters can often be tuned to control the amount of dimming they deliver.



ANTI-FRINGING

These filters can help you to combat the chromatic effects often seen through achromatic refractors, which most commonly take the form of noticeable blue or violet halos around bright stars. Hence these filters are also sometimes referred to as 'minus violet' filters. They can be used on any target.

bland disc of Venus. It has to be said, though, that filters can't perform feats of magic. There is still no filter in existence that acts as a cure-all for poor seeing or poor sky transparency.

Where to begin

Most astronomers, whether budding or experienced, are aware of colour filters, which are used for planetary work to tease out hidden details like the ones already described. But there are many more types, and they can cut down on lunar glare, help to reduce the insipid orange glow of streetlighting and even block out all light bar one specific wavelength, which can work wonders if you are keen on examining the denizens of the deep sky. We cover all of these in a bit more detail in the box above. Some filters can even be used together for an

enhanced effect, but bear in mind that stacking them in this manner will further dim the view.

If, once you have read up on all the different types, you decide filters might be of use to you, where should you begin? Many suggest a neutral density filter – otherwise known as the Moon filter. This one simply dims the view, and as such it is great for observing our close companion when it is in its dazzling fuller phases.

As always, if you can try before you buy, then do so – astronomical society events and the larger star parties around the country are both good opportunities to get some hands-on insight into the kinds of changes filters can deliver.

Once you're committed to making a purchase, be aware that you don't always have to buy filters individually: coloured

filters in particular are often sold in sets. If you get to the point that you are using a lot of filters, you may wish to consider another accessory, the filter wheel. Some are motorised, some are manually operated, but the basic premise is the same – they allow you to swap filters without having to remove your eyepiece each time.

Do be aware that all of the filters discussed here are intended for night-time use only. Under no circumstances should they be used to view the Sun, as they will do nothing to mitigate the dangerous intensity of its light. But, just as with any other object in the sky, the Sun's appearance changes once viewed through different (certified) filters. See page 76 for more on observing the Sun, and never view it without a certified solar filter in place.

ASTROPHOTOGRAPHY

Making a lasting record of the night sky's beauty with your camera is easier than it sounds – you may already own all the equipment you need to do it

Imaging the heavens is a fun and increasingly popular part of modern day astronomy, and thanks to advances in digital cameras it's also one that's never been easier or more affordable. With the right kit in hand, it will provide you with some lasting memories that will really show what an amazing Universe we all live in.

There are so many different ways to take pictures of the night sky that sorting out which method is right for you can seem almost as daunting as actually taking the images.

It's not as bad as it first seems, though. You don't need expert equipment, or even need a standalone camera – most likely, the smartphone in your pocket has a camera that's capable of taking a decent photo of the Moon through a telescope eyepiece.

You also don't have to wait for the sky to become completely dark. The Moon,

the bright planets and noctilucent clouds can all be seen in twilight skies.

The most versatile camera for new astro imagers is the DSLR, which can take wide-field shots of the sky while mounted on a tripod or attached to a telescope using an adaptor. They have features useful for astrophotography, including wide ISO ranges, interchangeable lenses and a bulb setting that allows you to hold the shutter open for as long as you want. They're self-contained, portable and can show you an image as soon as you've taken it, so you can adjust settings to get the shot just right.

Where to begin

When taking photos with a DSLR in low light, your camera's shutter will need to stay open for longer than it does in the daytime to gather the light it needs – perhaps several seconds. If you're holding the camera by hand, it will be almost impossible not to wobble it a bit during the exposure, and this will introduce blur to your photos. To get around this you'll need a steady tripod.

Another bit of kit called a cable release is useful. This allows you to

operate the shutter remotely and take a picture without causing any wobble as you press the capture button down. If your camera has a time-delay feature, which is when it waits for 10 seconds or so before taking the shot, it's just as good as a cable release. Turn on the timer, press the button, stand back and wait for the shutter to open and close.

Prosumer and compact cameras have come a long way in recent years, and provided that they offer the ability for you to alter their settings they can deliver excellent photos. There are also more specialist cameras – high frame rate and cooled CCD devices, which excel at planetary and deep-sky imaging respectively – but they are not ideal for beginners.

If you already own a small telescope you can also try the most straightforward imaging technique, afocal imaging. This is the technical name for simply pointing your camera down the eyepiece of your telescope. You can do this with a DSLR, a point and shoot, or even a smartphone. The hardest thing is making sure you hold your camera in line with the eyepiece and keep your hands steady.

“The smartphone in your pocket likely has a camera that's capable of taking a decent photo of the Moon”

LEARN HOW TO CAPTURE THE HEAVENS

Three great starter projects to get you started in astrophotography

PROJECT 1: TWILIGHT LANDSCAPE

This is a great way to start your astrophotography journey. Look for a composition that includes a twilight sky, a low crescent Moon, and maybe even a planet or two. You'll get a better picture if you can frame the shot with some trees or buildings that will silhouette themselves against the sky. If you have a DSLR, set it to manual mode so you can vary the results. Fix it to your tripod and open the camera's lens as wide as it will go. Turn off the autofocus, as the low light will cause it to hunt back and forth, then manually focus at infinity and use different exposure times until you get a pleasing result.



PROJECT 2: STAR TRAILS

The aim here is to capture the movement of the stars over time, showing you that Earth is spinning. As well as a tripod-mounted camera, you'll need a remote shutter release cable. The camera has to gaze at the heavens for a long time to show the movement – exposures can be anything from 15 minutes to a few hours. The longer you leave the camera shutter open the longer the star trails will be. On such long exposures, any light pollution will really show up, so the darker and clearer the skies the better. Make sure you include Polaris, the star around which the sky appears to rotate.



PROJECT 3: AFOCAL MOON SHOT

You'll need a telescope for this one, but any kind of camera will do – even the one in your smartphone. Focus it on the Moon, then hold the camera up to the eyepiece and click away. Getting the angle between the camera and the eyepiece right, then holding it steady, are the trickiest bits. Live view screens make this easier. For the best results, use an eyepiece with a long eye-relief, because the camera lens may not be able to get as close to the eyepiece as your eye and you'll miss some of the image. If your camera has a wider field of view than the eyepiece, you may get some darkening around the edges of the image.



JARGON BUSTER

EXPOSURE (SHUTTER SPEED)

The shutter speed determines how long the imaging chip is exposed to light that's been focused on it by the lens. In long exposures the shutter is open for longer, allowing more light to strike the camera sensor.

APERTURE (F/NUMBER)

This controls the amount of light that can reach the imaging sensor. The amount of light let in can be expanded or diminished with an iris in the lens that determines the f/number. A small f/number, for instance f/1.8, gives the widest aperture and lets the most light in. A large f/number, such as f/8,

lets less light in, but can give a sharper view due to an increase in focus depth.

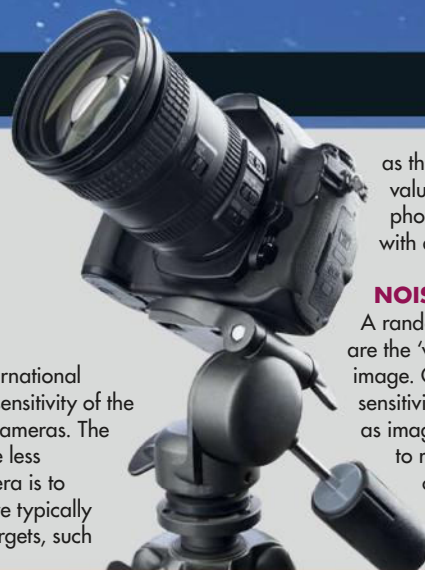
ISO SETTING (SENSITIVITY)

The ISO is an international standard for the sensitivity of the sensor in digital cameras. The lower the ISO, the less sensitive the camera is to light. Low ISOs are typically used for bright targets, such

as the full Moon. High ISO values around 3200 allow you to photograph faint subjects, but with a decrease in quality.

NOISE

A random pattern of pixels that are the 'wrong' colour across your image. Often the result of a high sensitivity setting, techniques such as image stacking can be used to reduce the effect. Modern cameras, especially those with larger sensors, suffer less from noise.





The Widescreen Centre

47 Dorset Street • London • W1U 7ND • Baker Street



Hot New Product!

SKYFI III

- Internal battery
- Apple or Android
- Serial or USB
- Call for details!



• Quality • Choice • Expertise • Service •

Welcome to the UK's Astronomy Showroom

See all your favourite brands in one place - in our showroom, at Star Parties & events, or at the International Astronomy Show



All the major brands under one roof! Tele Vue, Baader, Celestron, Avalon, Astronomik, Simulation Curriculum, Questar, Lunt, Daystar, Vixen, Sky-Watcher, Meade, Losmandy, APM, Officina Stellare, Software Bisque, PlaneWave, ZWO and many more. See the latest products and all your favourite brands; compare & contrast best-selling products and talk it over with one of our experts. From beginners through to those returning to the hobby, through to advanced imaging, home observatories and full-scale academic and professional installations - talk to us.

The Widescreen Centre really is the UK's one stop Astronomy shop. Whatever your Astro plans for the new season, call or email us today or see us at one of our many events. Call (020) 7935 2580 or email simon@widescreen-centre.co.uk



Photo courtesy Graham Smith, www.ukastroshow.com

Widescreen's Questar 3.5" from 1968 and a brand new 2016 model, 48 years later. What's changed? Very little. It's hard to improve on perfection. Call for more info.

Tele Vue's new Delite eyepieces - The 62° apparent field Delite retains the pure optical quality of Delos along with 20mm eye-relief & sliding, locking eyeguard, Dioptrix-ready. A joy to use. For daytime and night-time use, nothing comes close to Tele Vue. Switch to Tele Vue Optics today. You'll be glad you did. Complete your collection of accessories to last a lifetime.



Tele Vue Delite - now in 6 focal lengths 5, 7, 9, 11, 15 and 18.2mm. In store now.

New and Events September 2016

The Autumn Equinox Star Party - www.starparty.org.uk - is approaching. Join The Widescreen Centre at Kelling Heath Holiday Park the weekend of October 1st 2016. October 14-15th, IAS - the International Astronomy Show returns to Stoneleigh Park. Widescreen will be there on booths 35-36. For tickets: ukastroshow.com

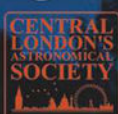
£Call



New CaH-line Quark at The Widescreen Centre now
DAYSTAR FILTERS

Are you getting enough Calcium? Building on the success of their phenomenal H-alpha Quarks, Daystar's new CaH Quark works at a less extreme wavelength than CaK, meaning more people can see it. Solar detail is the same, but it's easier to use. Even better, it's in stock now! However your current UV/IR block may block this region - but an Astronomik L1 does not. Whatever your summer Astronomy requires, we have everything you're going to need. See above - Star Adventurer mount • Manfrotto tabletop tripod • William Optics ZS71 & carbon fibre diagonal • Daystar Quark • ZWO camera • Tracer LiFePO4 battery • Astronomik L1 filter • Baader Herschel Wedge • Solar Continuum filter • Tele Vue Sol Searcher and Delite eyepieces • Pentax XF Zoom • and much, much more besides.

The Baker Street
Irregular Astronomers



Check the BSIA Website for the Next meeting date!

Join The Widescreen Centre and the BSIA in Regent's Park every month. Chance to check out our great products after dark. It's fun, it's free, and it's for everyone!

Visit bakerstreetastro.org or find us on Facebook or Twitter

PRICE MATCH

Shop with Confidence

- ✓ Best Products
- ✓ Best Deals
- ✓ Best Support

We'll match their price* and give you a little more - Service!
* conditions apply

Call: 020 7935 2580

47 Dorset Street • London • W1U 7ND • Baker Street

www.widescreen-centre.co.uk • 020 7935 2580 • simon@widescreen-centre.co.uk

WHAT TO SEE THE SOLAR SYSTEM

Our observing odyssey begins with our Solar System, the region of space we call home. It condensed out of the nebula in which the Sun formed, 4.5 billion years ago. A disc of debris circled the young Sun, its rocks and granules gradually sticking together to form larger and larger lumps that became the planets. Near the Sun, where it was so hot that volatile compounds evaporated, the rocky and metallic worlds Mercury, Venus, Earth and Mars were born. Farther away, where ices and gases

could survive, the gas giants Jupiter, Saturn, Uranus and Neptune formed.

They are just the tip of a very large iceberg – our Solar System is home to at least five dwarf planets and countless asteroids. We often see visitors from afar in the form of comets, and the debris they leave behind spawns annual meteor showers. Then of course there is the Moon, Earth's constant companion as it journeys around the Sun. We explain how you can see all of these and more over the following pages.

THE MOON

Our planet's only natural satellite is home to a wealth of interesting sights for all kinds of astronomers, and always has something new or interesting to show

The source of our ocean tides, subtle chronobiological cycles and the only other world that humankind has so far set foot upon, the Moon seems a familiar and tangible place. A quarter of Earth's diameter and just a quarter of a million miles away, it's 100 times closer than Venus. Given its proximity, brightness and large apparent size, it's easy to see why the Moon has enchanted humankind for centuries.

Pre-telescopic observers noticed an unchanging pattern of darker patches that would later become known as maria, or 'seas', because they were assumed to be vast bodies of water. They act as a Rorschach test for different cultures – the face of the 'Man in the

Moon' observed in Western tradition, the 'Rabbit' pounding rice of East Asian folklore, or the 'Lady Reading a Book' from the southern hemisphere, to give just three examples.

The reason we see the same lunar features staring back at us is because the Moon has a synchronous rotation with respect to Earth, meaning that spins once on its axis in the same 27.3 days (the sidereal month) it takes to complete an orbit of our planet.

It's equally obvious that the illumination of the Moon's Earth-facing hemisphere changes over the course of the month – a word, incidentally, that we get from 'Moon'. Although the Sun is always shining on a full half of the

Moon, the proportion of the lit side we are able to see depends on where the Moon is in its orbit around Earth, giving rise to the phases we see.

Imagine you are looking down on the Earth, Moon and Sun from above. When the three line up with the Moon in the middle, the Moon's lit half points away from us on Earth, producing a new Moon. Slowly emerging from its new phase into the evening sky, the lunar crescent thickens from one day to the next. The term 'waxing' is used to indicate this thickening phase. The waxing crescent leads to the Moon appearing as an illuminated semicircle roughly a week after new.

This is somewhat confusingly called 'first quarter', referring to the Moon's ►



position in its 29.5-day orbit rather than proportion of its disc is illuminated from our vantage point on Earth. The bulging phases after first quarter are known as waxing gibbous. These increase in size until, roughly two weeks after new, the Moon is on the opposite side of its orbit from the Sun and appears fully lit as a full Moon. The point of new and full Moon, when our planet, satellite and star are aligned, is known as a 'syzygy'.

After full Moon the phases reverse, and the illuminated part of the Moon begins to shrink or wane. After passing through the waning gibbous phases, the Moon reaches the three-quarter point of its orbit, giving rise to the 'last quarter'

phase. The Moon takes the appearance of a semicircle once again, although it's the opposite half that is illuminated than that at first quarter. After this, it takes approximately a week for the Moon to go through its waning crescent phases, visible in the early morning sky, before it once again becomes new again. It takes 29.5 days for the Moon to return to complete this cycle of phases or 'lunation', slightly longer than it does to complete an Earth orbit. This is known as a synodic month.

The Moon is the ideal place to begin your observing odyssey because it is big, bright and covered with amazing detail. But the thing that surprises most

novice observers is the variation it holds. Though the same hemisphere faces Earth at all times, what you can see on the Moon changes from night to night.

You may be forgiven for thinking that full Moon is the best time to examine our close companion – not so. While this is a good time to see the long, bright rays of ejecta surrounding prominent craters such as Tycho, the high altitude of the Sun in the lunar sky means no shadows are cast, resulting in a washed-out view of the Moon.

In general, the best time to view a given lunar feature is when the terminator, the demarcating line that separates lunar day and night, is nearby. This is the

THE MOON'S PHASES

The Moon's appearance changes because of its relative position to Earth and the Sun

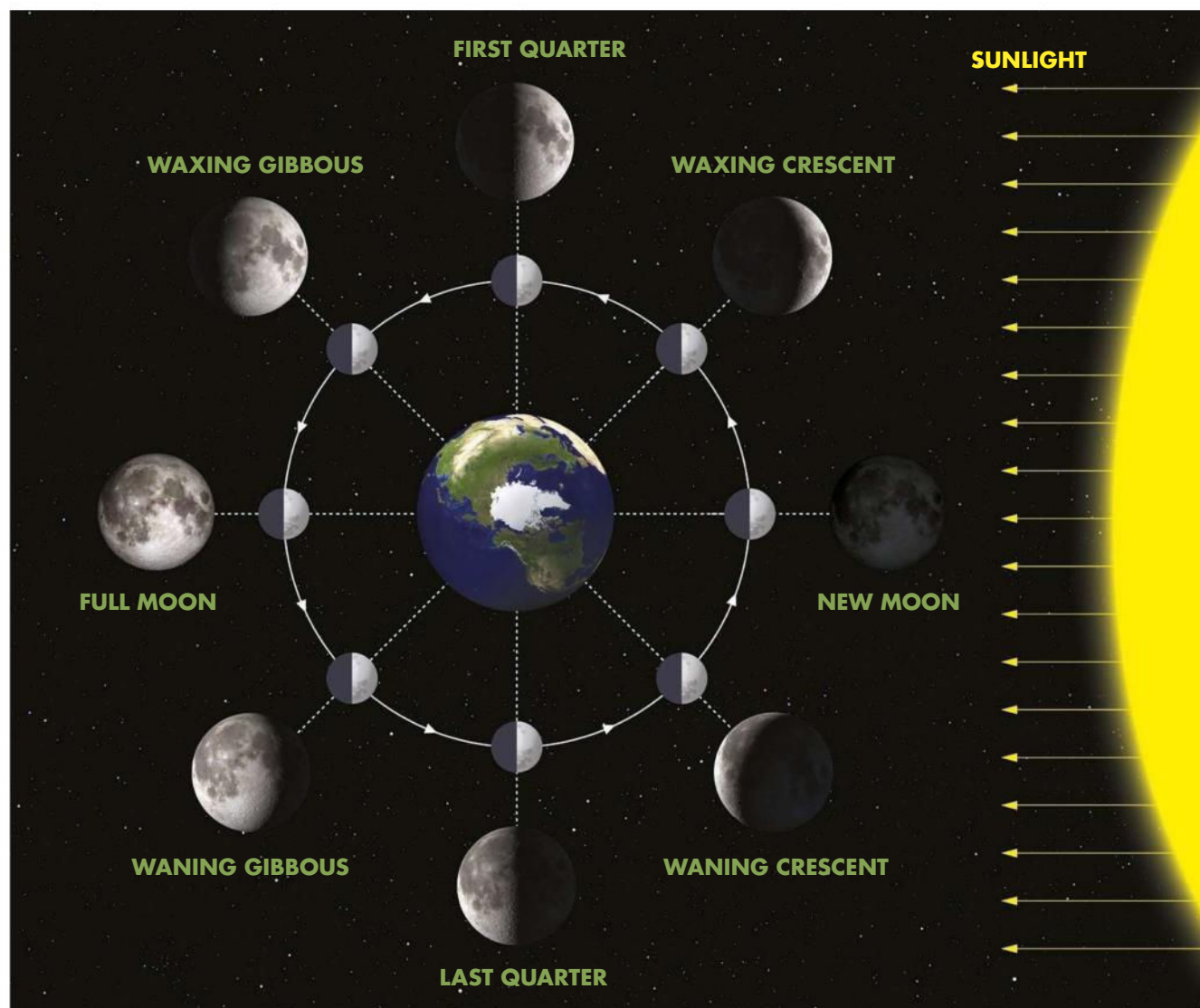


ILLUSTRATION STEVE MARSH, PHOTO LARRY LANDON/SCIENCE PHOTO LIBRARY

region where the Sun is either rising or setting, where crater rims and mountain peaks stand out in stark relief, casting inky black shadows across the lunar surface that exaggerate their presence. Those further from the terminator show hardly any shadows and are harder to make out.

At day zero of the lunar cycle – new Moon – the whole of the dark lunar hemisphere points towards Earth. Over the next 15 days the terminator slowly creeps across the lunar surface from east to west until the disc is fully illuminated at full Moon. Then the tables are reversed as the encroaching darkened hemisphere heads west with each passing day, until the diminishing crescent becomes lost in the pre-dawn twilight.

Moonrock and roll

The nature of the Moon's orbit generates another effect that is a boon to lunar observers, a rocking and rolling motion that we call libration. The Moon's orbit is elliptical, and as a result its distance from Earth does not remain constant. When closest it speeds up slightly; when more distant it slows down. This small variation is enough to cause the Moon to 'nod' back and forth on its axis, giving us an occasional chance to see a little more around its eastern and western edges.

The orbit is also slightly inclined, and this causes it to sometimes appear above the Earth's orbital plane and sometimes below. This gives us an opportunity to peek over the top, and under the bottom, of the Moon over time. Taken together, this libration allows us to see a total of 59 per cent of the Moon's globe, revealing

EARTHSHINE



The Moon is not solely lit by sunlight. When it is in a slender crescent phase in the evening or dawn twilight, it's sometimes

possible to see its dark portion gently glowing due to sunlight reflected off the oceans and clouds of planet Earth. This effect is

known as earthshine. Our planet actually reflects more light onto the lunar surface than the Moon gives us when it is full.

LUNAR LINGO

The Moon's features have Latin names – here's what they mean

Catena.....	Crater chain
Dorsum (pl. Dorsa)...	Mare ridge
Lacus.....	Lake
Mare (pl. Maria).....	Sea
Mons.....	Mountain
Montes.....	Mountain range
Oceanus.....	Ocean
Palus.....	Marsh
Promontorium.....	Cape
Rima (pl. Rimae).....	Fissure
Rupes.....	Escarpment
Sinus.....	Bay
Terre (pl. Terrae).....	Highland
Vallis.....	Valley

tantalising features normally hidden from our view.

With the naked eye it's easy to see the progression of lunar phases, full disc effects such as earthshine and the major lunar seas. Binoculars increase the detail you'll see: as well as dark seas, you'll now be able to spot individual craters and large mountain ranges, especially close to the terminator. The smallest craters you'll be able to pick out will depend on how still you can hold your binoculars, but a pair of 7x50s should comfortably reveal features down to about 50km across.

A telescopic view of the Moon is amazing and one that never gets old. At low magnifications, the amount of detail visible is breath-taking, especially close to the terminator where relief shadows really help to emphasise the detail. Upping magnification by using shorter focal length eyepieces will get you in

closer and give you opportunity to 'roam' around the lunar landscape.

The view you have of the Moon through a telescope will differ from what you see with the naked eye or binoculars depending on its optical arrangement. Through a refractor or compound instrument, the Moon will appear flipped west to east, while through a reflector the image will be inverted. With a telescope you may also notice the surface appears to gently wobble or sometimes even shimmer. This effect is caused by air moving through the atmosphere of our planet, and the greater the turbulence the worse the views.

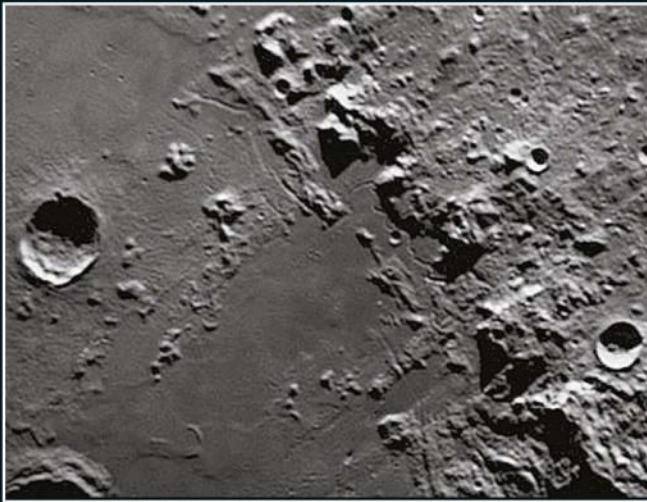
The 'seeing' can vary from minute to minute and night to night. The best views will always be when conditions are steady and the undulations are less intense; poor seeing, on the other hand, results in loss of detail and fuzzy lunar features.

TOP TEN MOON SIGHTS

Our celestial neighbour has enough to keep astronomers busy for a lifetime, but here are 10 highlights to get you started



WHAT TO SEE: SOLAR SYSTEM



1 HADLEY RILLE

EQUIPMENT: LARGE SCOPE

Famous as one of the features explored by the Apollo 15 astronauts, Hadley Rille is also a great target to look for with a large telescope. Under suitable illumination it appears as a little meandering black line near the northern end of the lunar Apennines.



4 CRATER PLATO

EQUIPMENT: SMALL SCOPE

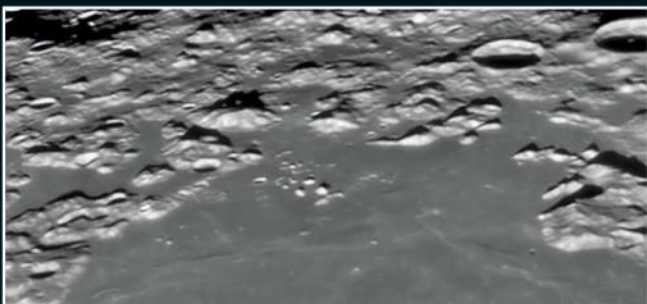
This beautiful 109km-wide crater lies nestled among the jagged landscape near the northern edge of the Mare Imbrium. It has a smooth floor and is surrounded by interesting features, including Rima Plato and the Montes Teneriffe.



5 THE LUNAR APENNINES

EQUIPMENT: SMALL SCOPE

The Apennines mountain range stretches over 900km across the lunar surface. It is particularly striking when lit from the side – when the peaks cast huge, inky black shadows onto the surrounding landscape.



9 MARE CRISIUM

EQUIPMENT: BINOCULARS

This 620x570km lunar sea is one of the most distinctive features on the Moon. Located close to the eastern limb, it's clearly visible to the naked eye as a dark oval patch. Unlike the other seas, the Mare Crisium is completely detached. Its dark, smooth-looking floor has a higher boundary that shows fantastic shadows as the terminator approaches and crosses the sea.



2 CRATER GRIMALDI

EQUIPMENT: BINOCULARS

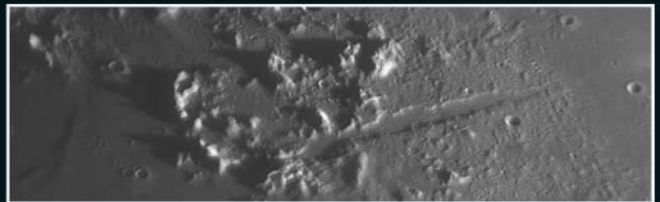
Visible to the naked eye, this dark, 173km-wide basin reveals lots of detail through binoculars and telescopes, including eroded walls, ridges and low hills.



3 CRATER COPERNICUS

EQUIPMENT: SMALL SCOPE

At the heart of a huge system of bright rays that spread for hundreds of kilometres, this 93km-wide crater has a distinctive terraced rim.



6 THE VALLIS ALPES

EQUIPMENT: SMALL SCOPE

Cutting through the lunar Alps, the 130km-long Vallis Alpes is one of the most interesting features on the Moon's surface. This valley can be spotted with even a small telescope.



7 CRATER GASSENDI

EQUIPMENT: SMALL SCOPE

A fascinating 110km crater on the northern edge of the Mare Humorum. Under the right light, you'll be able to see a superb network of rilles on its floor.



8 RUPES RECTA

EQUIPMENT: SMALL SCOPE

Best known as the Straight Wall, this 110km-long fault reaches over 270m above the lunar surface. Look for a thin black line near to crater Birt.



10 CRATERS PTOLEMAEUS, ALPHONSUS AND ARZACHEL

EQUIPMENT: SMALL SCOPE

These three imposing craters sit close to the centre of the Moon's near side. The largest of them, Ptolemaeus, has a smooth floor that is pockmarked with lots more tiny craters.

THE SUN

It's possible to see the amazingly dynamic nature of our nearest star in white light and hydrogen alpha*

*A hydrogen-alpha filter makes the Sun's disc appear slightly larger than a white light one because it reveals the chromosphere, which sits on top of the photosphere. Only the photosphere is visible through a white light filter.

WARNING

Do not look directly at the Sun with the naked eye or any unfiltered optical instruments

ACTIVE REGIONS

Sunspot groups, or active regions, take on a whole new appearance in hydrogen alpha. Dark sunspots become harder to see, partially hidden under the surrounding chromospheric blanket. Around them, dark fibrils follow the intense magnetic fields associated with these regions. Large, bright areas called plage appear throughout and around sunspot groups.

SPICULES

The edge of the Sun's disc seems to have a thin skin running around it. This is a cross-section of the chromosphere. Under good seeing you can make out that it's made up of tiny jets known as spicules. Together, they make the edge of the Sun appear 'furry'.

PROMINENCES AND FILAMENTS

Giant clouds of magnetically influenced hydrogen plasma can often be seen hanging off the edge of the Sun through a hydrogen-alpha filter. Known as prominences, these can change appearance day-to-day or, in extreme circumstances, real time. When seen against the chromosphere away from the limb, they appear dark and are known as filaments.

DYNAMIC BRIGHTENING

Active regions may also show dynamic bright regions. Tiny star-like points of light called Ellerman Bombs may come and go, each releasing the same energy as several million atomic bombs. Larger ribbons of light called flares are associated with magnetic reconnection events, which may throw out huge clouds of charged particles known as coronal mass ejections.

DARK MOTTLING

A hydrogen-alpha filter shows the Sun's inner layer of atmosphere, known as the chromosphere, which sits on top of the photosphere. This is covered in a coarse, magnetically influenced light and dark pattern collectively known as dark mottling. The pattern is visible across the entire disc and makes the Sun resemble a giant orange.

HYDROGEN ALPHA*

WHAT TO SEE: SOLAR SYSTEM

WHITE LIGHT



SUNSPOTS

Sunspots appear dark against the photosphere, often occurring in groups known as active regions. A typical sunspot shows a dark inner core called the umbra, and a lighter surrounding region called the penumbra. Sunspots appear dark because they are cooler than the surrounding photosphere.

FACULAE

The limb-darkened edge of the Sun's disc provides excellent contrast for viewing faculae. These are magnetically affected regions where the Sun's 'surface' becomes more transparent, allowing you to see into the deeper, hotter areas below.

LIMB DARKENING

When the Sun's disc is viewed through a white light filter, the centre appears brighter than the edge. This is called limb darkening, and occurs because at the centre of the disc you can see deeper into hotter, brighter layers.

GRANULATION

The Sun's visible surface, or photosphere, is covered in a fine pattern called solar granulation. This can be tricky to see and image as it's easily hidden by poor seeing. Granulation represents the tops of huge rising convective cells reaching the photosphere.



WAYS TO OBSERVE

From DIY to precision engineering, you can view the Sun in safety

PROJECTION



Solar projection is suitable for small refractors. The idea is to point the scope at the Sun and place a screen, typically a piece of white card, behind the telescope's eyepiece. This method can show solar granulation, dark sunspots and bright faculae.

WHITE LIGHT SOLAR FILTER



An inexpensive sheet of white light solar safety material can easily be fashioned into a filter for use with any type or size of amateur telescope. It's available in A4 sheets, and allows you to view and image granulation, sunspot groups and faculae.

PST

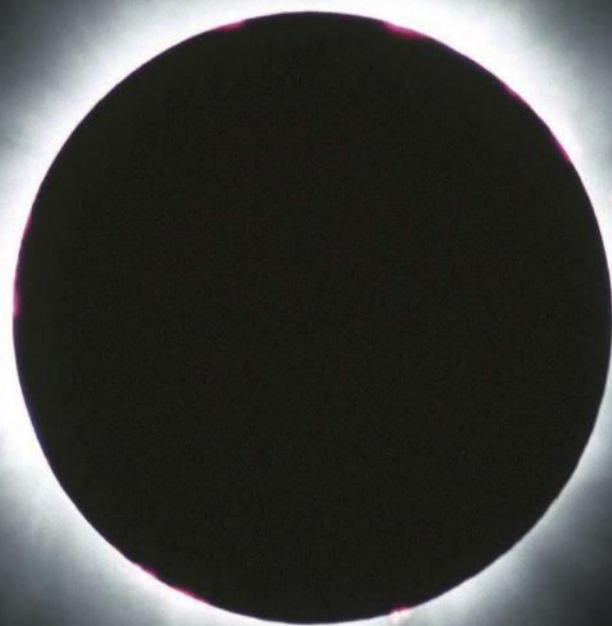


An entry level hydrogen-alpha scope such as the Coronado PST will set you back around £800. This instrument is able to show prominences, dark mottles, filaments and many of the bright phenomena associated with active regions, such as plage and flares.

H-ALPHA SCOPES AND FILTERS



For finer detail, larger aperture, narrower bandwidth hydrogen-alpha scopes are available, typically for several thousand to tens of thousands of pounds. Solar hydrogen-alpha filter kits in a similar price range can also be used to convert night-time telescopes.



The ancient Chinese thought that total solar eclipses were the Sun being eaten by a dragon – now we know better

SOLAR AND LUNAR ECLIPSES

Eclipses are eerily beautiful events involving the Sun, Earth and the Moon – and the result of a piece amazing cosmic good luck

When most people think of an eclipse, they think of totality, the apex of a total solar eclipse, where the Sun, Moon and Earth are in perfect alignment and the Moon completely covers the Sun. Even here, the Sun's light doesn't completely disappear. With the central brightness gone, it's possible to see the beautiful arcing curves of the Sun's corona, while Earth is plunged into a false twilight.

Totality can only be seen if you happen to be along a narrow corridor on the Earth's surface, known as the path of totality. Observers situated away from this track will see a partial eclipse of

varying magnitude, depending on their distance from it. Some parts of the Earth are so far from the track that they won't see an eclipse at all.

That total solar eclipses can happen at all is the result of a fantastic cosmic coincidence – the Moon is both 400 times smaller than the Sun and 400 times closer to us, so they appear to be the same size in the sky. Most of the time, at least.

The Moon's orbit around the Earth is not a perfect circle, which causes the Moon's apparent size to change over the course of each month by 14 per cent. When the Moon appears smallest it no longer fills the Sun's disc. When

eclipses happen during this time, they are annular instead of total: a thin ring of solar disc remains visible around the edge of the Moon's silhouette, and this can be just as beautiful as totality. There are also extremely rare hybrid eclipses, which transition from total to annular mid-event.

Align in the sky

We know solar eclipses occur when the Sun, Moon and Earth line up in the sky. Why then, don't we see eclipses every month at new Moon? It's because the Moon's orbit is inclined by 5.3° to the ecliptic, the plane in which Earth orbits

THE PHASES OF A SOLAR ECLIPSE

FIRST CONTACT

The point at which the Moon first touches the solar disc, marking the beginning of the eclipse

SECOND CONTACT

The moment the Moon is fully within the solar disc, marking the start of annularity or totality. Partial eclipses do not have second or third contacts

GREATEST ECLIPSE

The point of totality or annularity

THIRD CONTACT

The instant the lunar disc touches the other side of the solar disc, ending totality/annularity and marking the start of egress

FOURTH CONTACT

The point when the edge of the Moon's trailing edge breaks contact with the solar disc, ending the eclipse

the Sun. That means that even if the Earth, Moon and Sun are aligned in a straight line as seen from above (known as a 'syzygy'), the Moon may be too high above or too low below the orbital plane to block the Sun's light.

While every eclipse is partial somewhere on the planet, there are some during which the darkest part of the Moon's shadow misses the Earth, meaning there is no totality anywhere on the planet. This happened on 23 October 2014, when there was a partial eclipse that could be seen from North America – but in order to see totality you would have had to have been several hundred kilometres above the north pole.

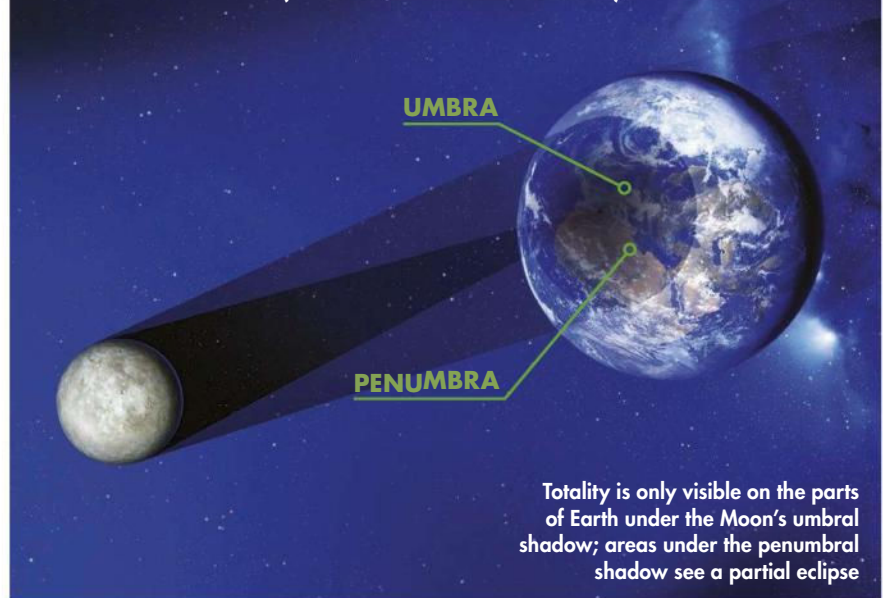
Like Sun, like Moon

Just as the Sun experiences eclipses, so does the Moon. Lunar eclipses, where the Moon passes into Earth's shadow, are more relaxed affairs than their solar counterparts, typically lasting for over an hour rather than a matter of minutes.

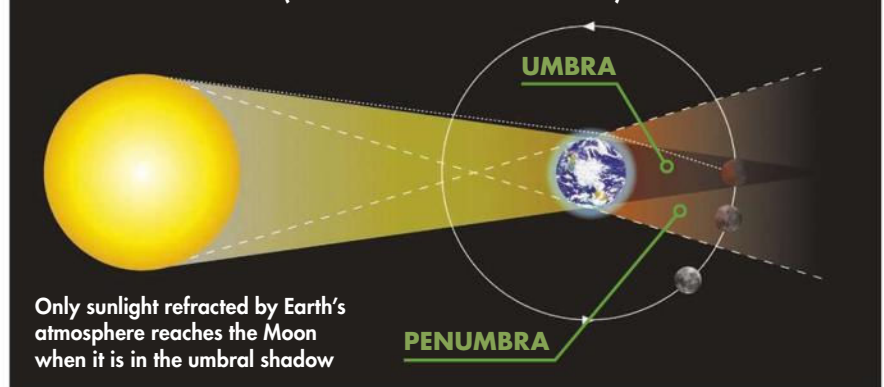
The intensity of a lunar eclipse depends on how much of the Moon passes into the Earth's shadow, and which part of the shadow it passes through from your viewpoint – the darker umbra or lighter penumbra.

During a total lunar eclipse, the entire Moon passes through the penumbra and into the umbra, gradually darkening until it is completely covered, a point known as totality. During totality no

SOLAR ECLIPSE (SUN-MOON-EARTH)



LUNAR ECLIPSE (SUN-EARTH-MOON)



sunlight shines directly on the Moon, but some is refracted onto it via Earth's atmosphere. As our atmosphere filters out blue light, the Moon often gains a strange orange-brown colour.

As the Moon goes into eclipse and dims, the sky gets darker too. You may not have realised how bright a full Moon can be. It lights up the sky around it with a blue haze, out of which only the brighter stars are visible. During a total lunar eclipse, the darker Moon means that the fainter stars can come out and we end up with the eerie sight of a deep-red Moon surrounded by twinkling stars.

How dark the Moon gets during a total lunar eclipse is described by the Danjon Scale, which runs from L0 through to L4. As the Moon is only lit by light that has passed through Earth's atmosphere, its precise colour and darkness will depend on how much dust, volcanic ash and water vapour is in the atmosphere to affect

the sunlight's path. The eclipse in 1884, after the huge volcanic eruption of Krakatoa, was so dark that the Moon could only just be made out, such was the amount of dust in the atmosphere.

There are two other types of lunar eclipse: partial, where only a portion of the Moon passes through Earth's dark umbral shadow, and penumbral, where part of the Moon only passes through the lighter, outer shadow. Partial eclipses can be quite noticeable, but penumbral eclipses often only cause a slight dimming.

Lunar eclipses can be observed without optical aids. For solar eclipses, you always need to use equipment with certified filters, or project the event onto a piece of card. The one exception is during the brief window of totality during a total solar eclipse. This is the only time it is safe to look directly at the Sun, and then only for a moment. The simple rule is: if you're not absolutely sure about safety, don't do it.

THE PLANETS

Our Solar System neighbours are popular targets for astronomers



NEPTUNE

The number of planets has changed over the years. Currently there are eight bodies recognised as planets and five as dwarf planets, including Pluto, Eris and Ceres. Pluto lost its planetary status in 2006, after other similar (and some larger) objects were found where it orbits. To meet today's definition of a planet, as well as being rounded by its own gravity and in orbit round the Sun, a body has to have cleared its orbit of other objects its size, which Pluto hasn't done.

All the planets move in the same anticlockwise direction around the Sun, if we take Earth's north pole as an arbitrary reference of 'up'. The Sun's gravity 'well' is immense – imagine a great bowling ball creating a dip in a trampoline. The planets are like marbles rolling along inside this dip around the bowling ball Sun. The closer they are to the Sun, the

stronger its pull of gravity and the faster it has to move to keep from being pulled into solar destruction.

All this speed, or lack of it, affects how a planet moves across the night sky as seen from Earth's surface. Whereas Saturn crawls around the sky, barely moving among the stars, Mercury's fast pace means it shifts considerably day by day. This is what the gravity of the Sun does, but there's also its light to consider. We only see the planets because the Sun lights them up. Their brightness is due to many things, including their actual distance from the Sun, the distance they are from your eye, and their size, composition and colour.

Mercury rising

Because Mercury and Venus are closer to the Sun than Earth, they are known as the inferior planets. The best time to observe them is when they are at their

farthest angular distance from the Sun, a position astronomers call elongation. At these times, the planets are only half lit by the Sun, but after this they swing back into the solar glare, where they become less visible. When Mercury and Venus are at eastern elongation, they set after the Sun in the evening; at western elongation they rise before the Sun in the morning. The Sun interferes with our views of the inferior planets twice during their orbits: when they all line up, the two points being known as inferior and superior conjunction.

The planets further out from Earth are called superior planets. These don't present the same problems for observers as Mercury and Venus in that they can be visible all night long. When any of them line up with Earth on the far side of the Sun, it is said to be in conjunction. The best time to observe the superior planets is when they are close to Earth. This happens at opposition, when the planet is on the opposite side of the sky to the Sun, so we are presented with a fully illuminated disc: visually it's close to or at its biggest and brightest.

“The Sun's gravity ‘well’ is immense – imagine a great bowling ball creating a dip in a trampoline”

MERCURY

VENUS

EARTH

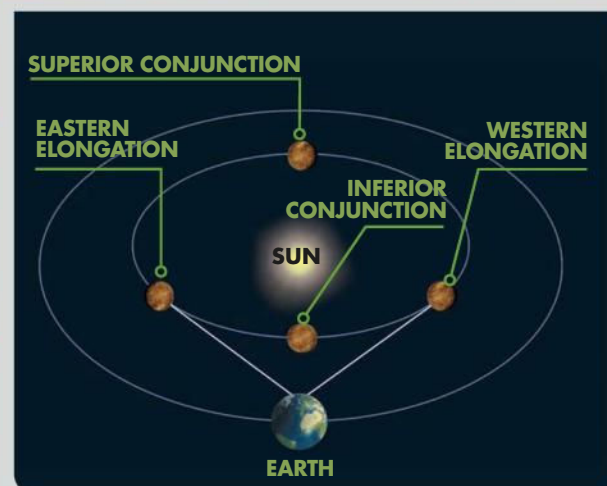
MARS

WHAT TO SEE: SOLAR SYSTEM

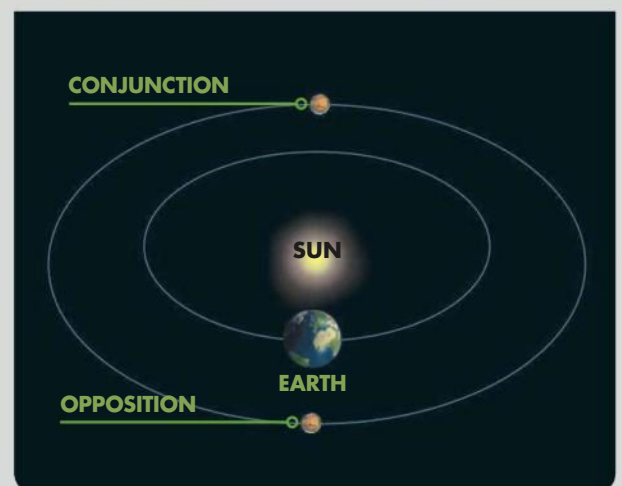


ASTEROID BELT

INFERIOR PLANETS



SUPERIOR PLANETS



THE ROCKY PLANETS

MERCURY

Diameter: 4,880km • **Moons:** 0 • **Distance from Sun:** 58 million km



The closest planet to the Sun, Mercury is a place of extremes. It is the smallest and densest planet in the Solar System, barely larger than our Moon. It takes 59 Earth days to rotate once, and 88 to orbit the Sun, meaning its parched surface experiences temperatures hot enough to melt lead on the sunward side, but is sub-Antarctic on the side in shadow.

This small world is a real challenge to observe for a variety of reasons. It's a fast mover, travelling around the Sun four times more quickly than Earth, so don't expect it to

hang about in any part of the sky for very long. Mercury's orbit is a fairly eccentric oval shape, and it's on a bit of a tilt too, which means some times are better for viewing it than others: spring evenings and autumn mornings. If that's not tricky enough, you only have a relatively short observation window on any day you choose to look, as Mercury never strays very far from the Sun.

In spring, start looking 30 minutes after sunset, after which you'll have about another 45 minutes to see it. Autumn gives you a longer view, from about an hour and 45 minutes before sunrise, but that does mean getting up exceedingly early.



DWARF PLANETS Diameter range: 975km to 2,330km

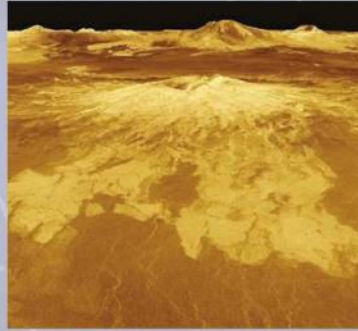
A dwarf planet is, according to the International Astronomical Union, a body that orbits the Sun (and is not a satellite), is spherical in shape (due to its own gravity), and is too small to have cleared its orbit of debris and so warrant being called a fully fledged planet. This classification was agreed after the 2005 discovery of Eris, an icy body in the outer Solar System very similar to Pluto, which was then considered a planet. In the fierce debate that followed Pluto was demoted into the newly created class, which also contains outer Solar System bodies Haumea and Makemake, and Ceres (pictured right) in the Asteroid Belt.

Ceres is the largest, but still comparatively small, so you will need binoculars to find it. Pluto is best seen by taking images of the region of sky it is in over consecutive nights and looking for the faint moving dot.



VENUS

Diameter: 12,100km • Moons: 0
Distance from Sun: 108 million km



Venus is sometimes called Earth's twin – occasionally its 'evil' twin. It is similar in size and composition to our planet, but a dense carbon dioxide atmosphere and sulphuric acid clouds make its surface a hellish 470°C. The planet spins slowly, in the opposite direction to most planets, and takes about the same time to rotate on its axis (243 Earth

days) as it does to travel around the Sun (225 days).

Because Venus's orbit is slower than Mercury's, it can be visible for months on end, and sometimes for up to three hours after sunset or before sunrise. When Venus is at its brightest, it becomes the third-brightest object in the sky, only beaten by the Moon and the Sun. This is caused by sunlight reflecting off its bright white carbon-dioxide clouds, and has led to Venus being called the 'Evening Star' or 'Morning Star' depending on when it appears. Venus can come very close to Earth, plus it's rather big, meaning that it's a good target for binoculars, through which you can easily see its larger phases.

MARS

Diameter: 6,800km • Moons: 2 • Distance from Sun: 228 million km

The Red Planet is the most visited extraterrestrial destination in the Solar System. Dozens of missions have ventured there, and they have explored the Martian landscape in incredible detail. Smaller than Earth but with the same land area, Mars is reminiscent of a cold rocky desert, littered by canyons and volcanoes. The planet has polar caps and a thin atmosphere of mostly carbon dioxide. Although dry today, Mars's mineral salts and rock formations suggest that it was wet in the past, and could possibly have harboured life.

Mars differs from Mercury and Venus in that its position in the Solar System – on the other side of Earth – means it can be 'up' from sunset until sunrise. A small telescope can reveal lighter, pale-reddish areas, the bright white of the ice caps, and darker patches, which it used to be thought were Martian 'cities'.



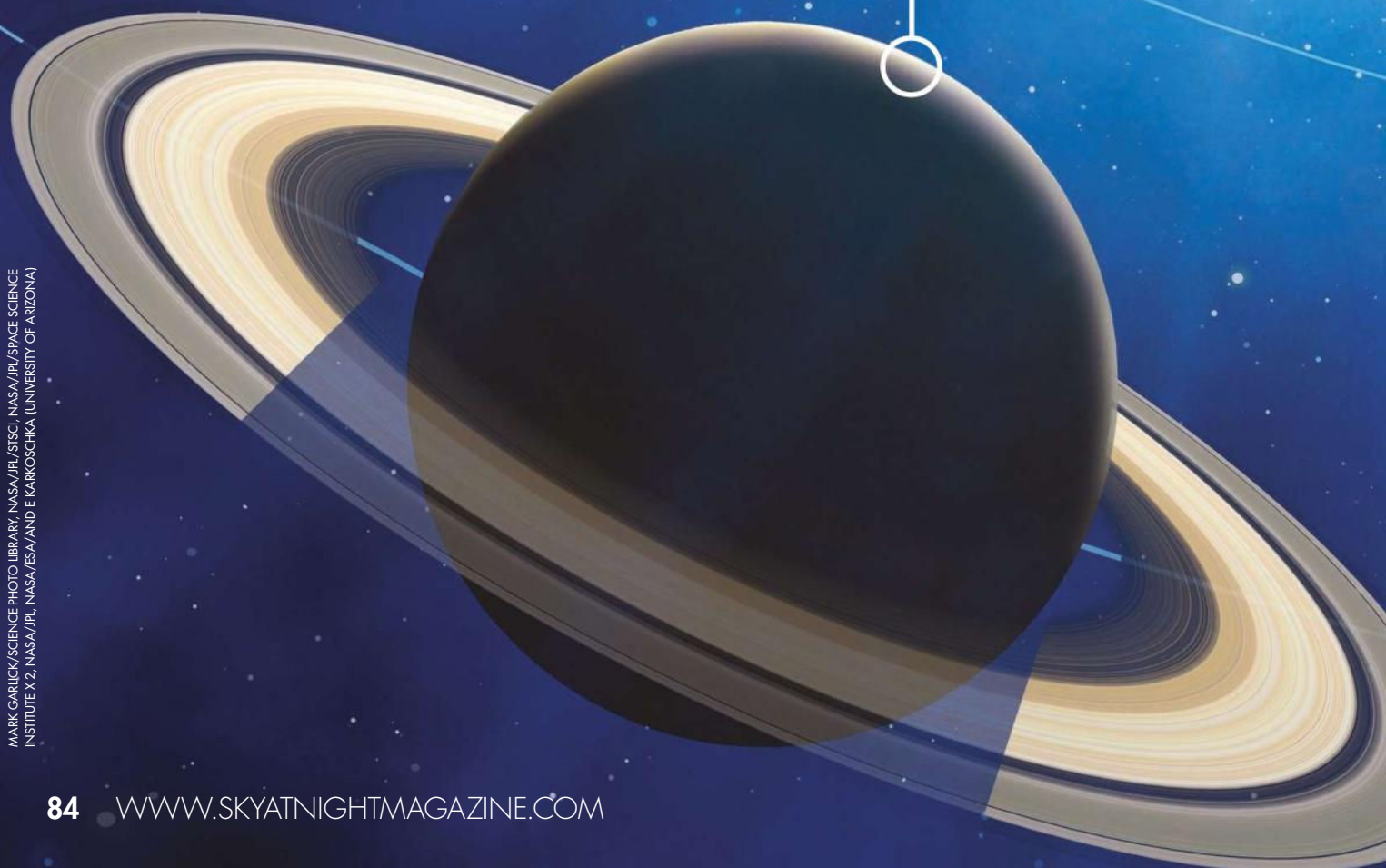
THE GAS AND ICE GIANTS

URANUS Diameter: 51,000km • Moons: 27 • Distance from Sun: 2.87 billion km



The first planet to be discovered with a telescope, found by William Herschel in 1781. Its blue-green hue comes from the abundance of methane ices in its hydrogen and helium atmosphere, which also contains water and ammonia ices. Like Venus, Uranus spins from east to west, but its axis of rotation is tilted almost 90° from the plane of its orbit, suggesting that it might have been knocked over by a collision. Five rings were discovered in 1977; in 1986 the Voyager spacecraft identified a further six, and two more were found by the Hubble Space Telescope in 2005, bringing the total to 13.

Visually, Uranus doesn't have much going for it, whether you use your eyes, a pair of binoculars or a telescope. By simply turning your head upwards, you can just about see this gaseous world as a very faint star at the limits of visibility (around mag. +5.6). You won't see much from anywhere with light pollution, however – the sky has to be very black indeed. The view does improve a little through a telescope, showing a greenish speck.



NEPTUNE

Diameter: 49,500km • **Moons:** 13 • **Distance from Sun:** 4.5 billion km



Neptune's composition is similar to that of Uranus, being mainly hydrogen and helium with methane-ices, water-ices and ammonia-ices mixed in. But unlike featureless Uranus, Neptune is wracked by stormy weather, with giant tempests boiling among the clouds. Its winds are the fastest in the Solar System, reaching an incredible 600m/s. Neptune has six known rings. They appear to have bright clumps within them, which may be short-lived collections of debris.

At around mag. +8.0 you need at least binoculars to see Neptune, and there isn't much else to say. Even when looked at through a telescope it looks like a 'star' with a hint of blue, but it is not as spectacular as its larger, closer compatriots. If you have a very large scope you can also catch a glimpse of Neptune's largest moon, Triton, which is mag. +13.5.

SATURN

Diameter: 120,500km • **Moons:** 62
Distance from Sun: 1.43 billion km

Saturn is known for its spectacular rings, made from millions of chunks of water-ice spread out into a thin disc only a few tens of metres thick but stretching 100,000km from the planet's surface. The rings form bands, some broad, some narrow. Scores of moons orbit within the rings, some carving out wide gaps. As with Jupiter, a handful of them are visible to amateur observers.

Saturn's brightness varies due to the way the rings are tilted and how much sunlight they reflect. The planet is not so bright when the rings are edge-on to us, but its brightness increases over 7.5 years as the rings open up to observers on Earth. Then it fades again over the same period. If you're wondering why this takes 7.5 years, it's a quarter of the time Saturn takes to go around the Sun.

The best way of understanding Saturn's tilting effect is to go out and look at the planet – it really is one of the telescopic marvels of the Solar System. It doesn't matter if you have a small scope: the sight of a world surrounded by rings is amazing. The view of this tiny ringed world hanging in a large, inky black field of view is magical. Larger scopes will start to show detail in the rings and on the planet.



JUPITER

Diameter: 143,000km • **Moons:** 67
Distance from Sun: 778 million km

The largest planet in the Solar System, Jupiter has more mass than all of the other planets put together and is second only to the Sun in terms of gravitational power. In 1994 it enticed comet Shoemaker-Levy 9 to fragment and crash into its swirling clouds; other likely comet crashes were recorded in 2009 and 2010. Jupiter is mostly gas, its composition of hydrogen and helium similar to that of the Sun.

With a good pair of binoculars the first things you'll notice are its four most famous moons: Io, Europa, Ganymede and Callisto, spied by Galileo Galilei in 1610. With a telescope you'll see a slightly squashed sphere. This is due to its fast spinning 'day' of just under 10 hours, which causes the equator to bulge outwards and the poles to flatten. Jupiter's cloudy atmosphere will be revealed as dark bands separated by white zones. The longer you look, the more features appear, so keep an eye out for spots, wisps and kinks. The most famous feature is, of course, the Great Red Spot, a storm that changes shape, size and colour over time, often appearing quite greyish.



THE MOONS OF JUPITER AND SATURN

The two huge gas giants are home to a staggering number of natural satellites

Jupiter is grandiose in all respects. Not only is it the largest of the planets – it would take 1,321 Earths to fill the volume of Jupiter – it's also more than likely that it keeps the largest entourage of moons. There are 67 that we know of, and though many of which are fairly small and can't be observed from Earth, the biggest four are easy to spot with just a small pair of binoculars.

These are Io, Europa, Ganymede and Callisto: the Galilean moons, so named because they were spotted by Galileo in the early 17th century.

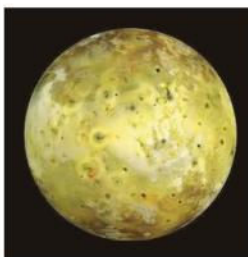
A minimum size pair for spotting these four moons would be 7x50s, which magnify what your eyes see seven times and have front lenses that are 50mm in diameter. Your view will be much improved by resting the binoculars on a wall or fence, or even attaching them to a tripod with an inexpensive bracket. Through a 3- to 6-inch telescope the moons will appear brighter and fill more of the field of view. Don't worry if you don't see all four: as the moons travel around the planet they may be behind or in front of Jupiter when you're looking.

It's by using a larger scope with a front lens over 6 inches that you start to see detail on the planet itself, and this includes the occasional shadow cast by the Galilean moons.

Moon with a view

Fellow gas giant Saturn has 62 known moons, but only seven are visible. Due to its sheer size, the easiest of Saturn's satellites to see is Titan. This moon has a diameter of 5,150km, which makes it bigger than the planet Mercury. In the moon rankings, it's the second largest in the Solar System, only beaten

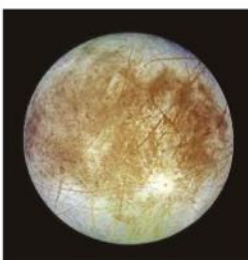
JUPITER'S FAMOUS GALILEAN MOONS



IO

Diameter: 3,640km

The tremendous gravitational pull of Jupiter on this innermost of the four Galilean moons, together with its closeness to the planet, means Io whizzes round Jupiter in just 1.75 Earth days. This fast orbital speed is easily seen in a small telescope: it visibly shifts position in just a few hours.



EUROPA

Diameter: 3,140km

The second Galilean moon out from Jupiter, Europa should theoretically be visible with the naked eye as it shines at mag. +5.3. But Jupiter's overwhelming brightness means it's difficult to separate moon from planet. Europa's brightness is due to its smooth, icy surface, with perhaps an ocean underneath.



GANYMEDE

Diameter: 5,260km

The third major moon out from the planet is not only Jupiter's biggest, it's also the largest moon in the entire Solar System – but only by a whisker. This is a world with a cold ice surface, a large warm ice (possibly water) mantle, a rocky interior and a liquid iron core.

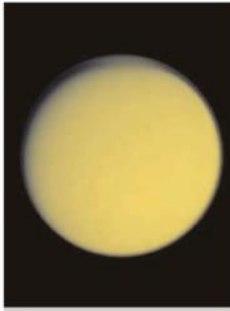


CALLISTO

Diameter: 4,820km

The last of the four giant Galilean satellites is Callisto. It is the third largest moon in the Solar System, after Titan, the biggest of Saturn's moons. Callisto's entire icy, ancient surface is covered with impact craters that date right back to the time of the early Solar System.

SATURN'S BEST MOONS TO OBSERVE



TITAN

Diameter: 5,152km
The largest of Saturn's moons has a 16-day orbit. At its farthest, you'll find it about five of Saturn's ring diameters from the planet, mag. +8.4 at its brightest, which makes it visible in good binoculars. Titan makes up over 96 per cent of the mass of everything orbiting the planet.



RHEA

Diameter: 1,528km
The second largest moon of Saturn, ninth largest in the Solar System, and currently the 20th catalogued in distance out from the planet. It makes an orbit in 4.5 days, reaching just under two ring diameters from Saturn. It is mag. +9.7, making Rhea an easy target for a 3-inch refractor telescope.



IAPETUS

Diameter: 1,469km
This is the third largest and most distant of the main moons of Saturn. Its 79-day orbit, which is the most inclined of the inner satellites, takes it out to 12 ring diameters from the planet. The visual magnitude ranges from +10.1 to +11.9, so Iapetus needs about a 6-inch scope to see it at its darkest.



DIONE

Diameter: 1,123km
This moon orbits up to 1.5 ring diameters from Saturn over 2.7 days. Its visual magnitude of +10.4 makes it visible on dark nights with a 3-inch refractor. This is the densest of the moons, meaning it may have a large rocky core. Helene and Polydeuces, two smaller moons, share its orbit.

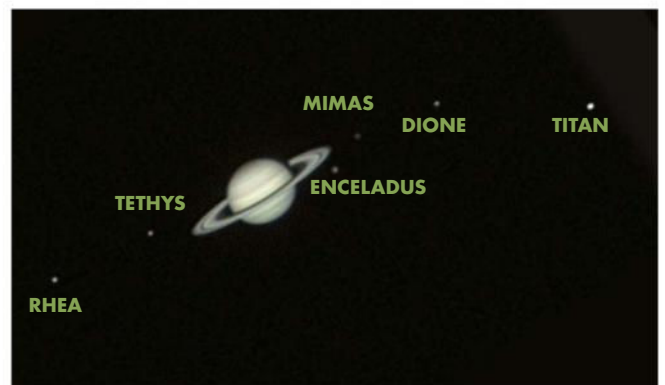


TETHYS

Diameter: 1,060km
This moon orbits about one ring diameter away from the planet and takes 1.9 days to do so. It has a magnitude of +10.3 and so can be seen in a 3-inch refractor. Tethys has a great canyon that stretches three-quarters of the way round the moon, and two co-orbital moons, Telesto and Calypso.



Jupiter's four Galilean moons can be seen in a telescope or binoculars



Saturn, being farther away than Jupiter, needs more magnification

by Jupiter's Ganymede. It's also the only moon with a substantial atmosphere. When you're gazing at it through your scope, you're not actually looking at Titan's surface but at its nitrogen-rich cloud tops. In terms of brightness, Titan can reach mag. +8.4, putting it well within the reach of binoculars, while with a small telescope you'll have no trouble seeing it.

The remaining six moons are all within the grasp of a 6-inch scope. In order of brightness, after Titan comes Rhea, which shines at mag. +9.7, Tethys at mag. +10.3, Dione at mag. +10.4,

Enceladus at mag. +11.8 and then quirky Iapetus.

The unusual nature of this last moon quickly became apparent to its discoverer in 1671, the Italian astronomer Giovanni Cassini. He first saw the moon on the western side of Saturn but found it missing on a later search, when it should have been on the eastern side.

It wasn't until 34 years later, when telescopes had improved, that Cassini finally saw Iapetus to the east, because when it's here it's almost two magnitudes fainter. This is why it had been impossible to see it before. Cassini deduced,

correctly, that this was because the moon has one very bright hemisphere and one very dark one, and is also tidally locked to Saturn.

This means, like our Moon, it always shows the same face to its planet. It follows that we see a different part of Iapetus from our Earthly viewpoint when it is to the east or west of Saturn. As a result, Iapetus varies between mag. +10.1 and mag. +11.9. However, the faintness trophy goes to Mimas, which at mag. +12.9, needs perfect viewing conditions without any light pollution to see comfortably.



Meteor showers are named after the constellation they seem to come from

METEORS

Bright streaks across the sky made by tiny pieces of comets or asteroids, meteors are a spectacular sight

You may know of meteors as ‘shooting stars’, but the truth is there is nothing stellar here. The dramatic, bright trails that slash across the sky comes from a much more innocuous source: a dust particle the size of a grain of sand colliding with Earth’s atmosphere, causing it to glow.

You can see several random, or sporadic, meteors per hour on any clear night, but a more reliable approach is to look for them during one of the annual meteor showers. These occur when Earth passes through the debris trail of a long-gone comet – a collection of debris just waiting to burn up in our planet’s atmosphere.

Meteor showers have what’s known as a ‘peak’, the night when you can expect to see the greatest number of meteors. The rates can vary quite substantially, but prominent displays such as the Perseids can produce an average of one meteor a minute under clear, moonless skies at

their peak. There is also the chance an unpredicted dense swarm of meteoroids could lie along the path of debris in the wake of a shower’s parent comet; the dynamics of all showers are not fully understood and surprises can occur.

Yet it is important to bear in mind that most major showers will be active over a period of at least a few days – and some for a few weeks – so you should not restrict your observing just to the dates of the predicted maxima. The vagaries of cloud cover and moonlight mean that you should always be vigilant during the week of the shower, spreading your observing opportunities to bolster chances of success.

Practical considerations

The first thing to consider when meteor hunting is where you are going to watch the shower from. If you happen to live in a light-polluted area you can vastly improve your observing experience

JARGON BUSTER

METEOROID

A piece of rocky debris in space that is smaller than an asteroid.

METEOR

A small piece of space debris, typically the size of a grain of sand, that has entered Earth’s atmosphere. Heating causes it to glow, causing streaks to appear in the sky. They’re popularly known as ‘shooting stars’.

METEORITE

A meteor that survives being burnt up in Earth’s atmosphere and crashes into the ground. Such fragments are useful sources of information about the history of the Solar System.

RADIANT

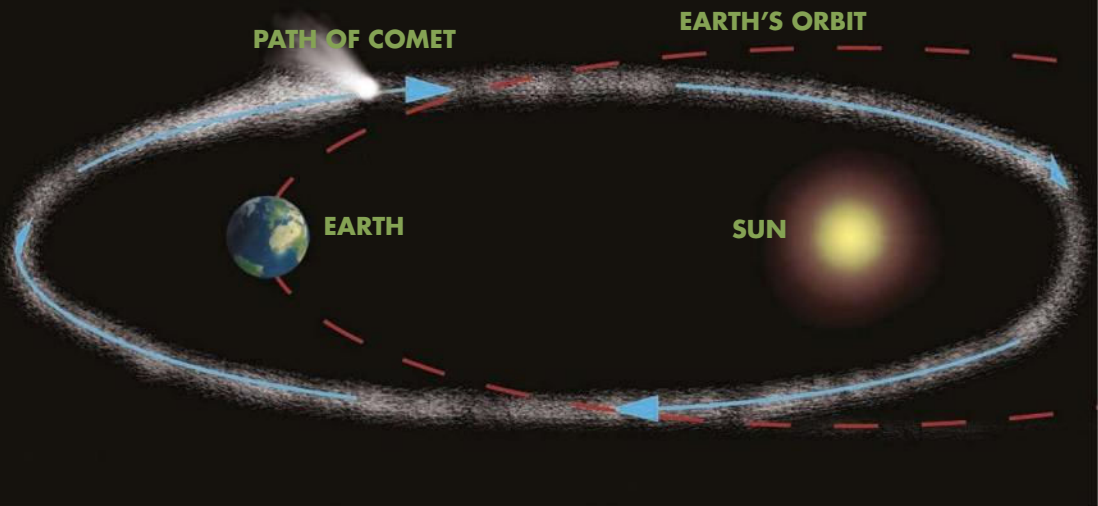
The radiant is the point in the sky where meteors (associated with a specific meteor shower) appear to come from. The constellation where the radiant is located determines the name of the meteor shower. So for example, the Orionids have their radiant in Orion.

ZENITHAL HOURLY RATE

A measure of meteor shower activity, ZHR refers to the number of meteors you would expect to see per hour under perfect conditions with the shower’s radiant overhead.

MAKING METEORS

By the time a comet approaches Earth, the Sun's heat has evaporated ice held by the comet. Much of the dust then follows the comet and, over time, can be spread out along the entire cometary orbit. When Earth intercepts this dusty path, lots of particles collide with the atmosphere and we see a meteor shower.



by travelling out of town to a more remote location, but be mindful of your personal safety. As with any form of observing it's important to be comfortable, but meteor-watching vigils in particular often require you to stay still for long periods.

Your best bet is to scour the sky from the comfort of a sunlounger or garden recliner. Since you'll be sitting for long periods it's important to keep warm, so

activity, when the sky is darkest and Earth's rotation faces into the direction of the planet's motion in space, giving additional swiftness to oncoming meteors. Don't look directly at the radiant, but concentrate your gaze high in the direction of the darkest portion of the sky that's free from obscuring trees and buildings. If you're observing in company, try to view different parts of the sky to each other so you catch as

“The best time to observe is shortly after midnight on the date of peak activity, when the sky is darkest”

wear a hat to prevent heat loss from the head and by all means snuggle into a sleeping bag. In the summer months you may also need to consider insect repellent. Bring along some food and a vacuum flask of your favourite hot beverage to drink at regular intervals – hydration is important, plus a little caffeine will certainly keep you alert.

Parallel lines

Debris from the same source tends to travel through space in parallel paths, so the effect of perspective means that their tracks through the atmosphere appear to converge on an area known as the 'radiant', where the meteors appear to emanate from. Meteor showers are named based on the constellation the radiant is in (and sometimes, the closest star).

The best time to observe is shortly after midnight on the date of predicted peak

activity, when the sky is darkest and Earth's rotation faces into the direction of the planet's motion in space, giving additional swiftness to oncoming meteors. Don't look directly at the radiant, but concentrate your gaze high in the direction of the darkest portion of the sky that's free from obscuring trees and buildings. If you're observing in company, try to view different parts of the sky to each other so you catch as

many meteors as possible. On occasions when the Moon is unavoidably in the sky, try to ensure that it's not in your field of vision or reflecting off nearby walls or windows, as this will seriously degrade your night vision. As with any other form of observing, your eyes need at least 20 minutes to reach peak sensitivity in darkness.

If you need to refer to star charts or books to find the radiant, it's best to use a dim red light rather than a white one so that you preserve your dark adaptation; if you use a smartphone app for this purpose, place a red cellophane filter over the screen. There's always a risk that you'll miss the best fireball of the night while taking notes, so it can be better to keep your eyes on the sky and use a voice recorder. Try to record the time, start and end points of the track and estimate the brightness of prominent meteors.

METEOR DIARY

QUADRANTIDS

Peak: Around 3 January
Max ZHR: 120 meteors per hour
Activity window: Early January

ETA AQUARIIDS

Peak: Around 6 May
Max ZHR: 60 meteors per hour
Activity window: Early May

PERSEIDS

Peak: Around 12 August
Max ZHR: 80 meteors per hour
Activity window: Mid July to mid August

ORIONIDS

Peak: Around 21 October
Max ZHR: 26 meteors per hour
Activity window: Mid to late October

LEONIDS

Peak: Around 18 November
Max ZHR: Usually 15 meteors per hour, but can be higher
Activity window: Mid to late November

GEMINIDS

Peak: Around 13 December
Max ZHR: 110 meteors per hour
Activity window: Mid to late December



Meteor trails often have tapered ends – this is one way you can tell it apart from a satellite

A spectacular comet visible to the naked eye can be given the title 'Great Comet' like C/2006 P1 McNaught

COMETS

The icy wanderers of the Solar System, spectacular comets may become visible only once in a lifetime

Wanderers of the Solar System, comets can be amongst the most spectacular of astronomical sights when they appear in our skies. These mysterious visitors never fail to capture imaginations when they pass by, and after years of careful observations astronomers have coaxed out the secrets hidden by their glow.

The heart of a comet is its nucleus, a core of ice laced with rock and dust, a

few kilometres wide. Though sometimes called a 'dirty snowball', the ice found on comets is far more exotic than that on Earth.

When the Rosetta spacecraft reached 67P/Churyumov-Gerasimenko it performed the first in-situ analysis of comet's nucleus, finding not only water ice, but also carbon dioxide and monoxide, as well as traces of

ammonia, methane and methanol. These highly volatile compounds are usually found as a gas or liquid on Earth, but the frigid depths of space have frozen them to ice as hard as rock.

These snowballs travel in huge elliptical orbits, briefly visiting the inner Solar System at one end before travelling billions of kilometres to the outer regions. Some, such as Halley's Comet, have an orbit that only takes a few years or decades and so are called short-period comets. Others, called long-period comets, travel much further into deep space, taking thousands of years to complete an orbit.

For most of these orbits, the nucleus remains an inert lump of ice, but this changes as the comet nears perihelion, its closest approach to the Sun. When close enough, the solar radiation heats the surface, causing the volatile components to boil. As the gas escapes into deep space it lifts off dust, creating a shroud that can stretch out over 50,000km around it – the coma.

Tale of a tail

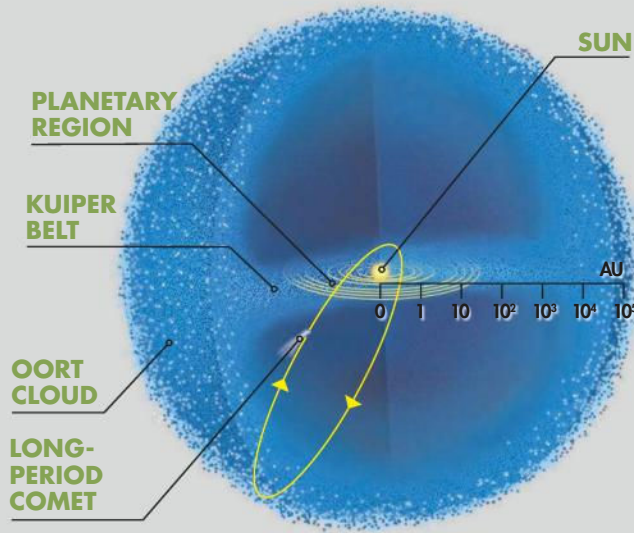
As the comet gets closer to the Sun, this envelope begins to feel the solar influence even more acutely, as its wind and magnetic field sweep the dust and gas out into a huge tail. This can extend for millions of kilometres, spanning huge swathes of the Solar System. Some of the tail's debris is left behind in its orbit to form a meteoroid stream. Several of these cross the Earth's orbit, and when we pass through them every year, we see the debris burning up in the atmosphere as a meteor shower.

For most comets, these close encounters with the Sun do little more harm than melting another layer off the nucleus. However, sometimes comets get too close, and the stresses caused by the intense heat and gravity cause them to break apart, as happened in December 2013 with comet C/2012 S1 ISON.

Sunlight reflecting off the coma and tail causes these celestial visitors to glow in the night, making them an ever-popular target for astronomers. Unlike the annual meteor showers their passing can create, comets are a much more transient phenomena adhering to a timetable all of their own. However, every year there are a handful of comets that can be seen with the aid of a small telescope. Websites such as International Comet Quarterly

WHERE DO THEY COME FROM?

After the planets formed, the remaining material coalesced into two regions. The inner of these, between 4.5 – 7.4 billion km out, is the Kuiper Belt. It's thought short-period comets come from here after being knocked out of orbit. Beyond this, the Oort Cloud stretches to 3.2 lightyears from the Sun. If a passing star kicks one of its bodies off course, it creates a long-period comet.



(www.icq.eps.harvard.edu/cometobs.html) and the British Astronomical Association's Comet Section (www.ast.cam.ac.uk/~jds) list all the comets that are currently active and visible with an amateur telescope, and where they might be found.

Even if we know when a comet is likely to appear and the path it will take, no one can guess what it will behave like once it approaches the inner Solar System. A comet could pass so close to the Sun that experts are sure it will be a spectacular view, only for it to break

apart during perihelion, or give little more than a fizz of a tail.

However, once in a decade or so there is a comet that passes close enough to Earth and is bright enough to be seen with the naked eye. When one of these is truly exceptional it may be bestowed the moniker of 'Great Comet'; an apparition so magnificent it is remembered for centuries (or even millennia) to come.

In the past comets were portents of death and war, but now these capricious visitors are a highlight for anyone lucky enough to see one as it passes by.

FAMOUS COMETS

Dominating the night sky or the landing site for a probe, these are among the best-known comets



HALE-BOPP

Closest approach: 136 million km
Period: 2,520-2,533 years
Famed for: Naked eye visible for a record 18 months in 1996/97, Hale Bopp captured public interest the world over. It will return around the year 4385.



67P/CHURYUMOV-GERASIMENKO

Closest approach: 186 million km
Period: 6.4 years
Famed for: Target of the Rosetta mission, which studied the comet from orbit and sent the Philae lander to its surface, where it found water and organic compounds.



GREAT DAYLIGHT COMET

Closest approach: 19 million km
Period: 57,300 years
Famed for: Spotted in January 1910, this comet quickly brightened until it outshone even Venus. Visible from both hemispheres, its tail was noticeably curved.



HALLEY'S COMET

Closest approach: 88 million km
Period: 75.3 years
Famed for: The only known short-period comet regularly visible to the naked eye from Earth, this regular visitor has been observed as early as 240 BC.

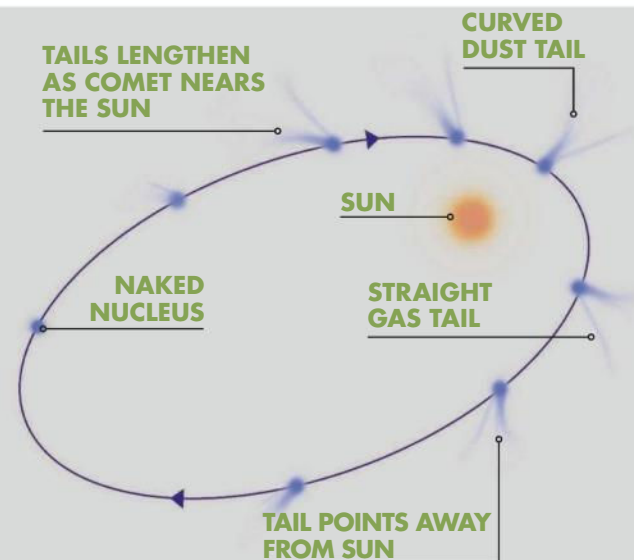


IKIYA-SEKI

Closest approach: 450,000 km
Period: 876.7 years
Famed for: Its 1965 close pass of the sun made Ikeya-Seki one of the brightest comets in 1,000 years. It's thought to be a fragment of the Great Comet of 1106.

CHASING THE TAIL

The most alluring part of a comet is surely its huge tail, but it's not always obvious is that there are two. The most apparent is the dust tail, swept out in an arc by the solar wind. However, the magnetic field captures the gas, forming a fainter second tail. Sometimes the comet's position relative to Earth means the tails appear to go in two different directions.



THE ISS AND OTHER SATELLITES

The Moon isn't the only object orbiting the Earth you can take a look at

There are two types of satellite visible in the night sky – natural ones like our Moon and artificial ones that we have placed up in orbit. Of all the artificial ones, the International Space Station, or ISS, is probably the best known. Easy to predict, its constant, often bright passage across the heavens is a sight that instils wonder.

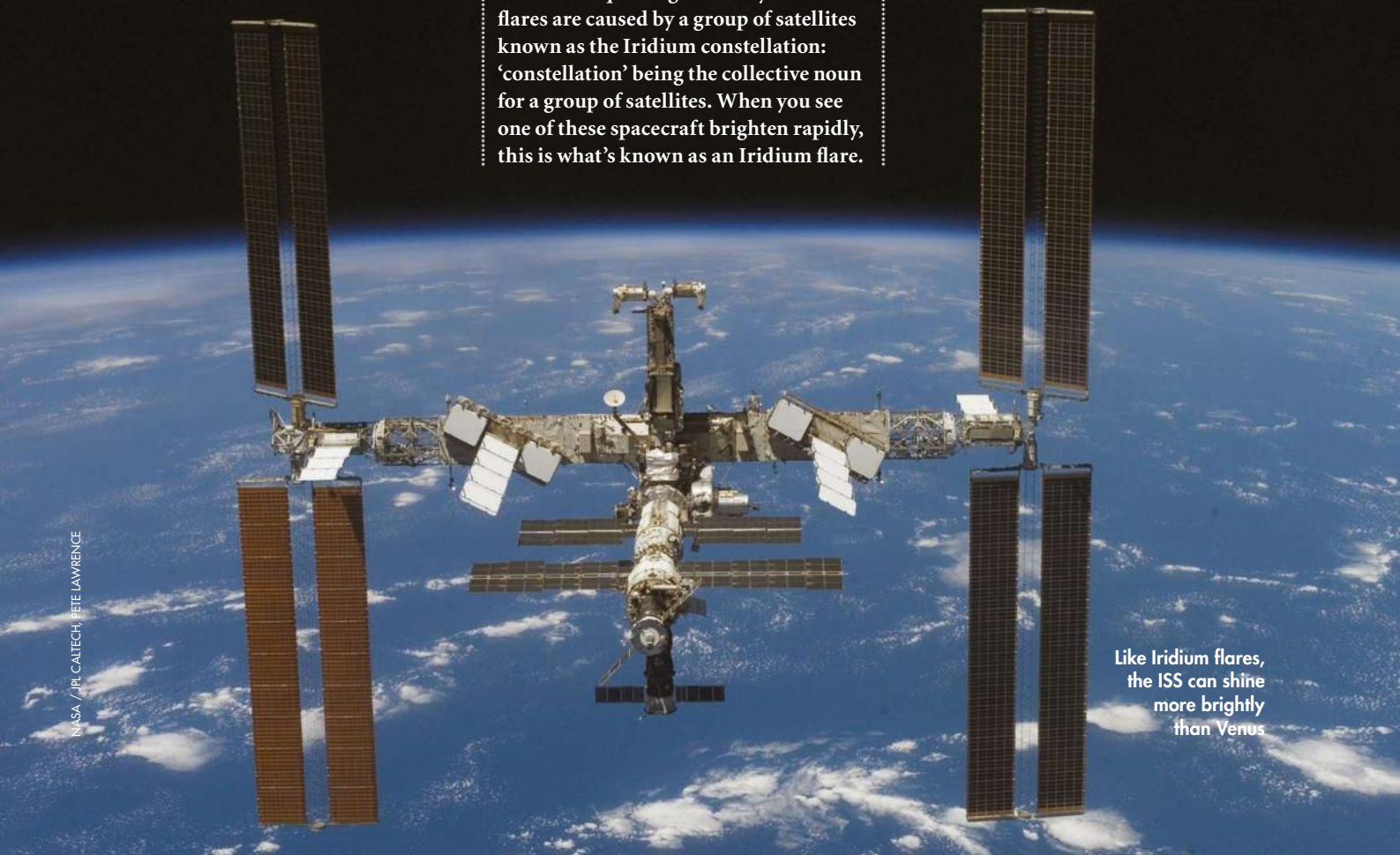
Humankind's orbital outpost typically appears as a dot, which gets brighter as it passes across the sky before fading again. Sometimes the ISS appears bright and then fades abruptly from view. The fading occurs when the

ISS's trajectory takes it into Earth's shadow, and as most sightings tend to be in the early evening the disappearance occurs when the ISS has reached the eastern half of the sky. If you're an early riser, Earth's shadow will be to the west. This causes the ISS to instantly 'switch on' as it passes out of the shadow back into full sunlight.

Solar power

It's the interaction of sunlight with the surface of a satellite that makes things interesting. Spacecraft that have large reflective areas can flare in brightness, sometimes quite significantly. The best flares are caused by a group of satellites known as the Iridium constellation: 'constellation' being the collective noun for a group of satellites. When you see one of these spacecraft brighten rapidly, this is what's known as an Iridium flare.

The science behind the flare is unremarkable in that each satellite in the constellation has three large flat, reflective antennas. When the Sun's light happens to hit an antenna at the right angle, it will appear bright when seen from a fairly localised region on Earth's surface. What is remarkable, however, is the fact that there are ways to predict, with down-to-the-second accuracy, when a flare can be seen from your location. And we're not talking faint, indistinct flaring here: some Iridium flares can increase the apparent brightness of the



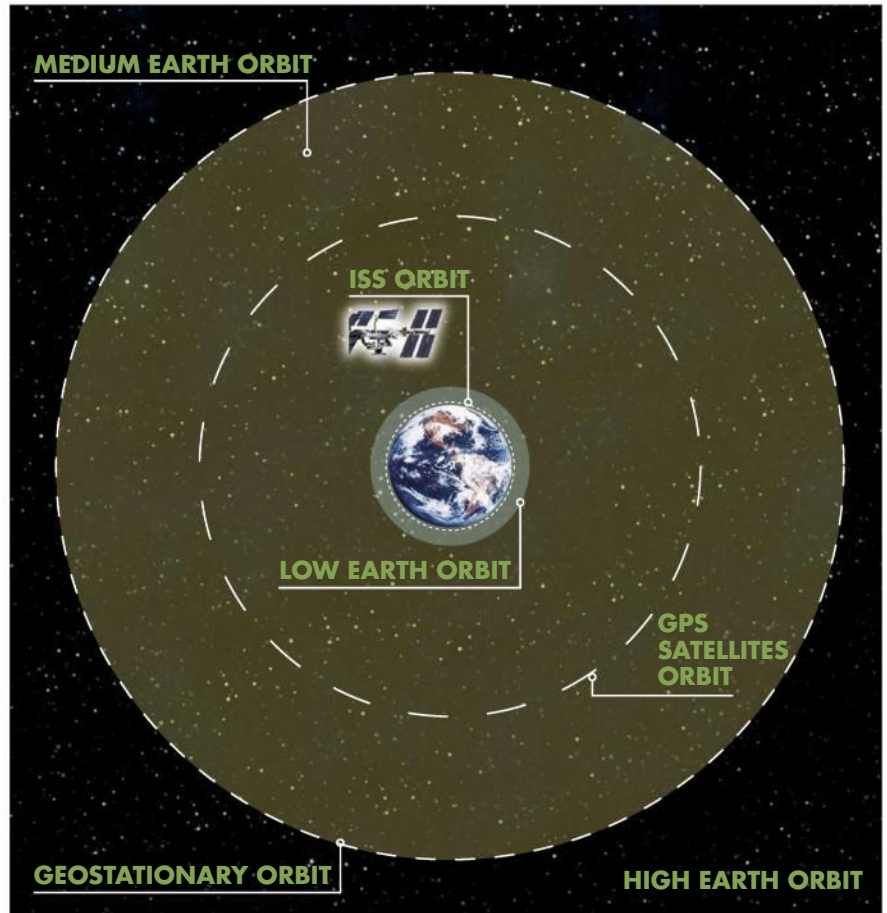


Iridium flares can become exceedingly bright; as dazzling as mag. -8.0

satellite's dot from that of a dim star to something brighter than Venus.

The brightest flares tend to be around mag. -8.0 , brilliant enough to easily illuminate any thin clouds that may get in the way. In theory, such a bright pass could even cast shadows – not that anyone ever looks behind them when a flare occurs! Not all Iridium flares will reach this brightness, of course; the flare may not be optimal and you may be located away from the position on Earth where the brightness of the flare peaks.

Other satellites can also show flare activity and it soon becomes obvious, especially to meteor imagers, that flaring spacecraft occur all the time. A flaring satellite that reaches peak brightness and



There are three distinct orbits where a satellite can be inserted into orbit around planet Earth. The International Space Station is close to home in low Earth orbit, at an altitude of around 400km

PREDICTING A PASS

There are many different ways to predict satellite passes – some more reliable than others

HEAVENS ABOVE

One of the most popular and respected methods is to use the website Heavens Above (www.heavens-above.com). You can create a free account that logs your location and generates visibility predictions for many different satellites. Sky charts accompany visible passes, and clicking on the date of the pass will typically bring up an all-sky chart showing the passage of the satellite among the stars. So long as you have a basic knowledge of the constellations then the track, adjusted for your location, should be pretty

easy to identify. As an added bonus, if you don't know the stars that well, then this is a good way to have some fun while learning the night sky.

OTHER PREDICTION SITES AND APPS

For the slightly more technically minded, there are many excellent programs available to download such as WXTrack (www.satsignal.eu/software/wxtrack.htm), which is able to predict the passage of many satellites directly from a Windows PC. Apps for other operating systems, including smartphones are also available; many are listed in a 'satellite tracking software index' at <http://celestrak.com/software/satellite/sat-trak.asp>. Some of these programs are

commercial, requiring you to purchase a licence to use them, but there are plenty of freeware options available too.

ENSURING ACCURACY

One problem with computer predictions is reliability. This could be down to problems with the program itself, or that you haven't set your location, date or time properly. And if satellite data isn't updated regularly, this too may affect accuracy. If doubts start to creep in, compare the predictions for an easy to identify satellite, such as the ISS, with Heavens Above. If they don't match, update the software's satellite data, and your time and location details, before trying another program.

is then rudely truncated by the camera shutter closing will look very similar to what you'd expect to see from a bright meteor trail.

It's possible to tell the difference by looking carefully at the brightest end of the trail. If the trail looks perfectly smooth and is cut off squarely at the brightest end, then it's either a rare meteor trail interrupted in its prime or – much more likely – a flaring satellite trail that wasn't allowed to complete its display before the camera shutter closed. Iridium flares also tend to record as white trails, while meteor trails often exhibit a pink start changing to green – an effect caused by the excitation of atoms in our atmosphere.

There are over 1,000 operational satellites orbiting Earth and an estimated 21,000 objects larger than 10cm. If you widen the net and include objects down to 1cm in size, the count moves beyond half a million. In fact, on any clear, moonless night, it would be unusual not to see an artificial satellite passing through the constellations, appearing as a moving dot among the stars.

NOCTILUCENT CLOUDS

These eerie, glowing blue clouds can be seen in summer skies

From late May through to early August, there is an intriguing and unusual observing target that is only visible in summer's twilight skies – the eerie blue tendrils of noctilucent clouds.

Noctilucent clouds, also known as night shining clouds and more commonly referred to by the abbreviation NLCs, were only discovered in 1885, following the 1883 Krakatoa eruption. The massive explosion of this Indonesian volcano had an impact all over the world, dropping temperatures by 1.2°C, generating eye-catching sunsets, and leading to an increased awareness of related atmospheric phenomena.

NLCs are located in the upper fringes of Earth's atmosphere and are therefore a quite distinct and separate cloud type from the familiar weather or 'tropospheric' clouds of the lower atmosphere. They form in the mesosphere, just below the mesopause (the coldest part of the atmosphere), in a thin sheet at an average height of around 82km, close to the edge of space.

The precise nature of these clouds is not yet fully understood, but they are thought to form when water vapour condenses onto minute atmospheric particles and freezes. The most likely sources of such particles would be meteor debris (meteors can vaporise at around 100km, above the NLC layer) or volcanic activity. Studies indicate that NLCs need extremely cold temperatures, around -120°C, to form. The mesosphere is at its coolest in summer, which explains NLCs' seasonal behaviour.

NLCs only become visible against a twilight sky when the Sun lies between 6° and 16° below the horizon. Any less than 6° below the horizon and the background sky is too bright, swamping the fainter light of NLCs; on the other hand, if the Sun is more than 16° below the horizon, then the NLC sheet lies in the Earth's shadow, becoming invisible.

This 'Sun-Earth-Observer' geometry imposes geographic restrictions on NLC visibility, as does the physical location of

the NLC sheet itself, which is generally located from 60° to 80° latitude in each hemisphere. This explains why the bulk of NLC sightings are made from within the latitude band of 50° to 65°, which conveniently encompasses the UK and Ireland. Nonetheless, NLCs can be, and are, observed from outside this area. Rare, isolated sightings have been made from as far south as 40° latitude, both from Europe and the US.

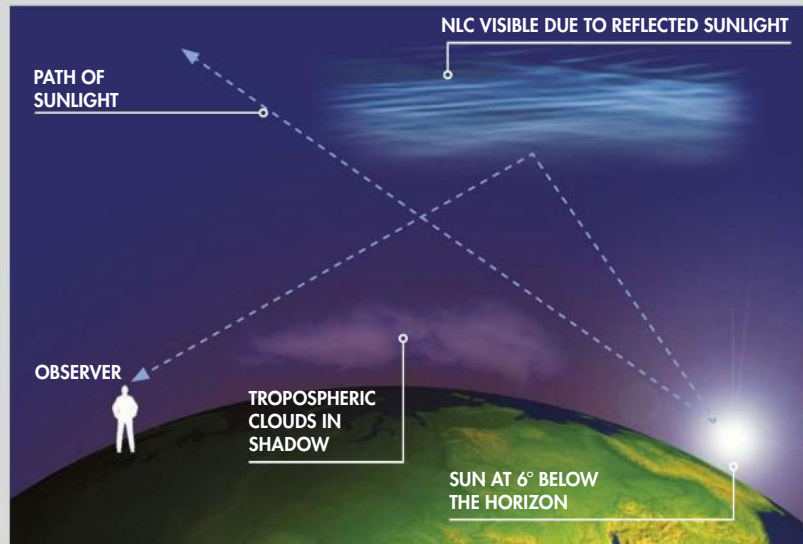
Pattern recognition

Each year, NLCs become visible in a fairly predictable pattern. The earliest sightings usually come near the end of May or early June, when cooling of the mesosphere sets in. Early sightings are normally of weak, simple formations, but as the season progresses displays tend to be brighter, more complex, endure for longer and occupy larger areas of sky. Records show a clear peak in activity from around mid-June through to mid-July, by which time the season starts to gradually tail

WHY DO WE SEE NLCs?

UK observers can see NLCs due to a bit of fortunate geometry. When the Sun is between 6° and 16° below the horizon, its light will hit any NLCs present in the

mesosphere, making them visible from Earth at latitudes of around 50° to 65°. Beyond this range, NLCs appear much less frequently.



off. By early August the season is all but over, though rare sightings have been made later in that month.

Wispy streaks

A typical display will commence about an hour or so after sunset, initially appearing as faint, wispy streaks, perhaps extending only a few degrees above the horizon. As the night unfolds and the twilight sky darkens, the NLCs become more obvious and may rise higher in the sky, often developing more intricate structure and becoming noticeably brighter. As local midnight nears, NLCs may fade somewhat and shrink in size as the solar illumination becomes less favourable. But after midnight, this pattern of behaviour is reversed: NLCs get brighter and stronger again until they are

swamped by the brightening sky, perhaps an hour or so before dawn.

NLCs can be easily misidentified. The key thing to remember is that weather clouds generally appear dark, silhouetted against the twilight, whereas NLCs will always appear

brighter than the background sky, often exhibiting a signature bluish tone. Nonetheless,

thin streaks of cirrus cloud, especially if illuminated by moonlight, can bear a striking resemblance to NLCs, and low bands of horizon haze can also create false impressions of Type II

NLC bands. A good test to

perform on any suspected NLCs is to examine the feature with binoculars. Tropospheric clouds tend to remain diffuse and blurred when magnified, while NLCs almost always reveal levels of finer detail.

WHEN'S THE BEST TIME TO LOOK FOR NLCs?

Typically 90-120 minutes after sunset, low in the northwest, or for a similar period before sunrise low in the northeast.

NLC STRUCTURES



TYPE I: VEIL

This type of NLCs appear as a patchy, fibrous sheet with little or no obvious structure, sometimes visible in the background of other forms. It can look like a glowing fog or mist.



TYPE II: BANDS

These NLCs feature horizontal lines or streaks that can be sharp (Type IIa) or diffuse (Type IIb). The bands may be parallel, or meet and cross.



TYPE III: BILLOWS

A distinctive structure of rippled or wavy bands, Type III NLCs are often compared to the sand patterns formed on a beach at low tide.



TYPE IV: WHIRLS

Looped, curved or twisted forms. Small whirls can be classed as Type IVa, medium size as IVb and large scale loops as IVc.

AUORAL DISPLAYS

These dancing curtains of light are magnificent, but not always easy to see

Shimmering, flickering drapes, rays and coroneae – the aurora is one of the most dynamic displays that the natural world, let alone the night sky, can offer. It gives us, here on the rocky surface of planet Earth, a rare and fleeting glimpse of how we are connected to the unseen forces at play out in space.

While some more energetic displays have been visible as far south as the UK, aurorae are more common if you're under the auroral oval. Centred on Earth's magnetic poles, the ovals trace rings of dancing light that roughly follow the Arctic and Antarctic Circles, and the best chances to view the aurora are from countries within this region. In the Arctic Circle this phenomenon is known as the aurora borealis, or Northern Lights; in the Antarctic Circle it is the aurora australis, or Southern Lights.

Auroral displays are caused by charged particles streaming out of the Sun and interacting with Earth's magnetic field – our planet's protective shield – which channels them down towards the

magnetic poles. As the particles reach lower altitudes, usually between 80km and 200km, they hit and excite the gases in Earth's atmosphere, causing a distinctive and colourful glow. This is far above the height that passenger aircraft typically fly (around 10km), but the International Space Station and other manned spacecraft have flown through the upper reaches of an energetic display, giving rise to some stunning views.

The magnetic poles are about 11° away from the geographical poles (the ones traditionally referred to as the North and South Poles). So you stand a much better chance of seeing all this activity in far northern or southern latitudes.

See the light

To observe them, you don't need a telescope or even binoculars: the best view is with your own eyes as their wide field of view is best suited to taking in the play of light across large parts of the sky.

An auroral display can take many forms and can change very quickly.

A general glow stretching across the sky from east to west is called an arc and usually has a well-defined lower edge. If the arc has an irregular lower edge, then it is known as a band.

Another common shape witnessed in a display are rays, which look like shafts of light stretching upwards into the sky and are, in effect, a direct way of seeing the Earth's magnetic field lines. These can occur on their own or in a group. If an arc or band contains rays, then it is known as a rayed arc or rayed band. If a

TOP TIPS FOR AURORA WATCHING

- Check space weather sites such as aurorawatch.lancs.ac.uk and spaceweather.com for aurora alerts.
- The further north you are, the better your chances of witnessing a display.
- Position yourself with a clear view of the northern horizon, where displays will appear.

band shows kinks and folds, these are known as curtains or drapery. Patches are just that – an auroral glow that has no particular shape and can come and go. Veils are a general glow covering more of the sky, but with little structure. In a very large and active display, the rays may even appear to converge directly above you, giving rise to an auroral crown or corona.

Aurora observers also add descriptions about how quickly a display changes. If it just hangs there in the sky with little or no movement, then it's said to be quiet. If it fades and brightens, a display can be called pulsating. When the aurora displays rapid but subtle changes, it is said to be flickering, while dramatic and quick-changing features – especially in the rays – are flaming. Lastly, streaming occurs along the length of a band when a bright patch ripples along it.

Whether you see colour in an auroral display depends on its brightness. Faint displays will appear monochrome, with differing shades of grey. However, most commonly the aurora has a green colour – light given off by oxygen in our atmosphere. Red can also be present, especially in the upper rays, as this colour comes from oxygen higher in our atmosphere, while blues and purples can appear in very bright displays when nitrogen becomes excited.

Brightness and contrast

There's an internationally recognised scale for measuring the brightness of the aurora, called the International Brightness Coefficient (IBC). This runs from I to IV – faint to bright. An IBC I display is about the brightness of the Milky Way, with minimal colour present. IBC II looks similar to moonlit cirrus cloud and may have a slight greenish colour. IBC III is similar to bright, moonlit, low-altitude clouds with obvious colour, while IBC IV is bright enough to read by, and to cast shadows.

In the past, auroral displays were difficult to predict, but now satellites such as the Solar Dynamics Observatory constantly monitor the Sun and the solar wind it throws off to provide early warning of its effects on Earth. There are several websites with email alert services that give early warning for potential displays, and with these space weather reports, we're better prepared than ever before for witnessing a display. All that remains then is for the local weather to play ball as well.

AUROL STRUCTURES



ARCS

An auroral arc: a general glow across the sky with a well-defined lower edge



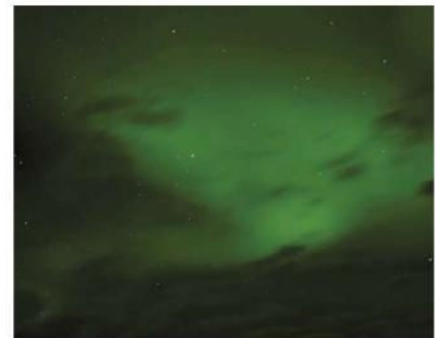
CURTAINS

A curtain aurora: a band of light that shows kinks and folds along its length



BANDS

An auroral band: similar to an arc but with an irregular lower edge



PATCHES

A patch aurora: these appear as a glow that has no particular shape



RAYS

Ray aurora: these present themselves as shafts of light stretching up into the sky



VEILS

An auroral veil: a general glow covering the sky with little structure to it



RAYED BANDS & ARCS

Rayed bands and arcs: similar structure to bands or arcs, also containing rays



CORONAE

A corona: rays that appear to converge at a point directly overhead

**SPECIAL
EDITION**

THE COMPLETE GUIDE TO ASTROPHOTOGRAPHY

FROM THE MAKERS OF

BBC Sky at Night
MAGAZINE

The night sky is teeming with spectacular sights just waiting to be imaged, but where do you begin? *The Complete Guide to Astrophotography* has the answer. Inside you'll find a course like no other – all the techniques and tutorials you need to progress from simple smartphone imaging to fully autoguided deep-sky shots, plus in-depth processing advice.

***Plus – subscribers to BBC Sky at Night Magazine receive FREE UK P&P**



Learn the techniques needed for each class of celestial body, from our Solar System's planets to the denizens of the deep sky



Astrophotography masterclasses in each section will help you put what you learn into practice on popular imaging targets



Discover tried and tested techniques to tweak your astrophotos in post processing, with tutorials to guide you along the way

ORDER YOUR COPY TODAY
www.buysubscriptions.com/astrophoto

Alternatively call 0844 844 0254[†] and quote 'ASTHA16'

[†]Calls will cost 7p per minute plus your telephone company's access charge. Lines are open 8am-8pm weekdays & 9am-1pm Saturday.
*UK subscribers to BBC Sky at Night Magazine receive FREE P&P on this special edition. Prices including postage are: £9.49 for all other UK residents, £10.99 for Europe and £11.49 for Rest of World. All orders subject to availability. Please allow 28 days for delivery.

WHAT TO SEE THE DEEP SKY

If the Solar System is Earth's backyard, then the Milky Way – the Galaxy that we live in – is our cosmic neighbourhood. It contains hundreds of billions of stars and thousands of nebulae, clouds of dense gas. Most lie within either the fat ellipsoidal bulge at the centre of the Milky Way or in the flat disc that surrounds it. Encircling the whole Galaxy is a sparse spherical halo of stars, as well

as a collection of dense globular clusters. We can even see other galaxies, beyond the Milky Way, some of which are much larger than our own.

Over the following pages we'll introduce you to some of the best targets in each class of deep-sky object, exploring how you can see these celestial wonders for yourself, including the equipment you'll need and where in the sky you can find them.

We can't get a camera outside our own Galaxy yet, but this is what we think it looks like



THE MILKY WAY

We may only be able to see it from the inside, but our Galaxy shines at night

Our Galaxy, the Milky Way, is one of the most magical sights of the night. Away from light-polluted regions our Galaxy looks like a river of light. It becomes clearly visible every year as autumn approaches, the brightest part of it adorning our skies.

The term Milky Way can refer to several different objects, as well as a famous chocolate bar. Some use it to refer to the weaving band of light that crosses the sky, created by the hundreds of thousands of faint, distant stars

whose light combines to form this wonderful feature.

However, there's much more to our Galaxy than these stars, which are just the visible part of it. The term Milky Way is also used to describe our entire Galaxy, a huge island of stars of which our Sun is a member. If we were to look down at our Galaxy from afar, as shown in the image above, the view would look much like a spinning Catherine wheel firework.

This particular 'firework' is made up of somewhere between 200 and 400 billion

stars, and is believed to be around 3.2 billion years old. From its bright, bulging centre emanate several arms, which spiral outwards. A closer look reveals that these spiral arms come out of the ends of a bar that runs through the central bulge.

Barred spiral

This means that the Milky Way is a member of the class of galaxies known as barred spirals. The arms form what's known as the galactic disc, where the majority of stars live, including the Sun.

OUR GALAXY'S PLACE IN THE UNIVERSE

And because of all the dust and gas that floats there, the arms are also where new stars are being born. Beyond that, outside the main disc, there's a halo containing hundreds of huge, spherical groups of stars known as globular clusters.

Needless to say, all of this is big. Very big. Our Galaxy has a diameter of around 100,000 lightyears, while the spiral arms have a thickness of between 1,000 and 2,000 lightyears. A lightyear is the distance that light can travel in one year.

Our star, the Sun, sits about 25,000 lightyears from the centre, on the edge of what is known as the Orion-Cygnus Arm. This is a minor spiral arm of the Galaxy that sits between the major Sagittarius-Carina Arm inside it and the Perseus Arm on the outside.

How do we know this? Well, as soon as telescopes were powerful enough to make out the spirals of other galaxies, we began piecing together the similarities between those that were far off and our own. And once astronomers were able to peer into the skies with radio and infrared telescopes, they were able to see through the dust and gas that stops observations of visible light – and saw the stars in the galactic arms beyond. We certainly don't know everything yet, but advances in technology in the years to come are likely to reveal much more about our Galaxy.

The Milky Way isn't alone in our part of the Universe. Beyond the clusters of stars that form a halo around us, we have a number of neighbours. Together these are part of what's called the Local Group, a family of about 30 big and small galaxies sitting in an area of space around 10 million lightyears in diameter.

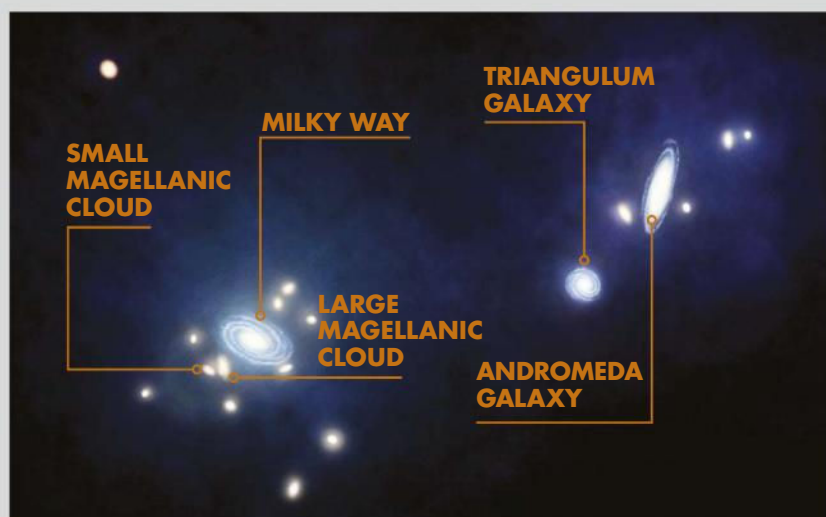
We are in one of the big three galaxies within the

group, the other two being the Andromeda Galaxy and the Triangulum Galaxy. The rest are fairly small dwarf-type galaxies, some of which are satellites of the big three. The most famous satellite galaxies of the Milky Way are the Large and Small Magellanic Clouds. These can only be seen from the southern hemisphere and look like round pieces of

the Milky Way that have broken off.

The Local Group is itself part of a larger structure, a number of nearby groups and clusters that make up the Virgo Supercluster.

And that formation too, stretching over hundreds of millions of lightyears, is just one of many superclusters in the Universe, linked by thread-like filaments of galaxies.



HOW TO SEE THE MILKY WAY FOR YOURSELF

From Earth we see the stars of our Galaxy in a band all around us because of our position within the disc of the Milky Way. However, they're not evenly spread around the sky. If you look in the direction of the constellations Orion and Monoceros, you are basically looking out of the main disc into deep space. There are fewer stars there and so the Milky Way is less noticeable. Look in the opposite direction, towards Sagittarius and Scorpius, and you're looking directly into the heart of our Galaxy. Here there's much more dust, gas and stars. The Milky Way is visible all year round, but it's higher in the sky in April and September.

M20, the Trifid Nebula, is an unusual combination of an open star cluster and three types of nebula

THE MESSIER CATALOGUE

How a Frenchman's 18th-century list of objects to avoid became the definitive catalogue for amateur astronomers

For budding and seasoned stargazers in the northern hemisphere, the Messier Catalogue is the most famous observing list of astronomical deep-sky objects. Within the 110-strong catalogue are examples of every known deep-sky object – a good assortment of galaxies, open and globular star clusters, nebulae and one supernova remnant: the famous Crab Nebula in Taurus, which is also the first object in the catalogue. It bears the designation Messier 1, commonly written as M1.

Messier's catalogue has become so ingrained into astronomical lore that objects are commonly described by their Messier number. So 'M42' is often used in place of, or in addition to, the name of the object, in this case the Orion Nebula.

The irony of this useful catalogue is that it was never intended to be a list of

objects for observers to hunt down with their telescopes: rather, it was a list of objects to avoid. This is because Charles Messier, the French astronomer who created the catalogue, was a comet hunter, and many comets appear as faint, fuzzy blobs in the sky – just as deep-sky objects do. So he assembled these deep-sky objects into a list of 'red herrings', in order to make sure they could be discounted during his cometary searches. He conducted these in his observatory, a wood and glass structure atop a tower in the medieval Hôtel de Cluny in Paris.

Growing number

The Messier Catalogue first arrived on the scene in 1771 as a list of 45 objects. Ten years later it had been expanded to 103, with some of the later

observations being undertaken by Messier's assistant Pierre Méchain. The catalogue stayed at this size for over 100 years. There were some interesting developments in the 20th century, as astronomers and historians made seven additions to the list. These were not just arbitrary objects, but ones that Messier and Méchain made observing notes about shortly after the final version of the catalogue was published. It was only in 1967 when M110, a faint dwarf elliptical galaxy in the constellation of Andromeda, made its way into the catalogue as the final officially recognised object.

There are several reasons why Charles Messier's 'list of objects to avoid when looking for comets' has become so readily accepted as targets to seek out with a telescope. One is that it isn't too long: 110

TOP NAKED-EYE MESSIER OBJECTS



M42 RA 05h 35m 17s
dec. -05° 23' 28"
The Orion Nebula is a vast cloud of dust and gas – what's known as an emission nebula, and is a star-forming region. It's easy to spot with just your eyes as a misty patch below the three belt stars in the constellation of Orion.



M45 RA 03h 45m 48s
dec. +24° 22' 00"
The Pleiades, also known as the Seven Sisters, is an open star cluster in the constellation of Taurus. Depending on your eyesight and how dark the sky is at your location, you'll be able to see between six and 12 stars.



M13 RA 16h 41m 42s
dec. +36° 28' 00"
The hundreds of thousands of stars that make up the Great Globular Cluster in Hercules are just visible to the eye from dark locations. It's one-third of the way south of a line between the stars Eta and Zeta Herculis.



M31 RA 00h 42m 42s
dec. +41° 16' 00"
The Andromeda Galaxy is without doubt the most distant object visible to the naked eye, being about 2.8 million lightyears away. Find it in the constellation of Andromeda as a faint smudge in very dark, Moonless skies.

TOP SMALL-SCOPE MESSIER OBJECTS



M81 RA 09h 55m 33s
dec. +69° 03' 55"
Looking at Bode's Galaxy in the constellation of Ursa Major with a 3- to 4-inch scope, you'll see it as the brighter of two fuzzy patches close to each other in the night sky. The second patch is another galaxy, the fainter M82.



M51 RA 13h 30m 00s
dec. +47° 16' 00"
The Whirlpool Galaxy in the constellation of Canes Venatici is a face-on spiral galaxy. Small scopes reveal the basic shape and the smaller companion with which it is interacting. Larger instruments reveal more structure.



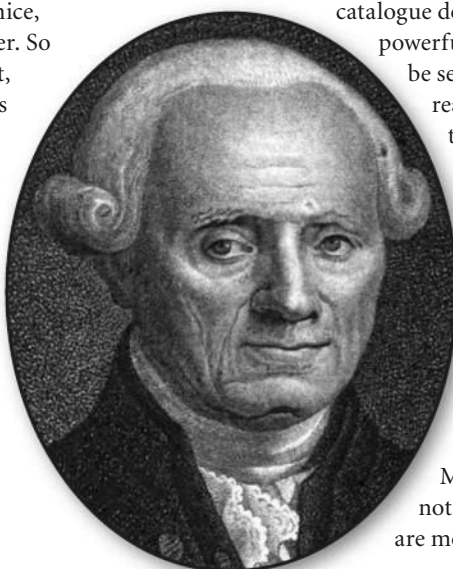
M3 RA 13h 42m 12s
dec. +28° 23' 00"
This globular cluster, also in Canes Venatici, is an easy target for a small telescope – though it can be tricky to locate. It's one of the largest and brightest globulars in the sky; a small scope will reveal great detail and a compact core.



M57 RA 18h 53m 35s
dec. +33° 01' 45"
The Ring Nebula in the constellation of Lyra is a shapely planetary nebula, and one of the easiest of its kind to observe. With a 3- to 4-inch scope it's easily seen as a misty but quite defined oval patch.

objects makes it a nice, manageable number. So manageable, in fact, that some amateurs like to undertake Messier marathons, where they endeavour to observe all 110 objects in one night.

Another reason is that Messier used a variety of different sized scopes in his comet searches, including a 3.5-inch refractor. The objects in his



Charles Messier intended his catalogue to be a list of things to avoid

catalogue don't need massively powerful instruments to be seen: they're within reach of small amateur telescopes. Finally, it's a reasonably comprehensive list, encompassing almost all of the wondrous sights that novice stargazers would wish to see, many of them bright objects. Of course, the Messier Catalogue is not the only list – there are more than 110 objects out in space after all. The New General Catalogue

(NGC), for example, lists nearly 8,000 objects, followed by an extension known as the Index Catalogue (IC) that adds more than 5,000 on top. You'll also find that many objects appear in multiple catalogues: M42, the Orion Nebula, is also designated as NGC 1976. However, the NGC and IC lists are little more than databases of deep-sky objects. They have less appeal for amateur astronomers because many of their entries are too faint to see without a professional telescope.

There is, however, one other list that's worth a mention: Patrick Moore's own compilation, the Caldwell Catalogue. This is, in effect, an extension to the Messier Catalogue. It includes many more bright, deep-sky objects that are perfect for you to train your telescope on from your back garden.

DOUBLE STARS

The sight of two stars partnered together can be truly stunning, especially when they have vibrant colours. But don't confuse your binaries with your optical doubles...

After the invention of the telescope in the early 17th century, the true nature of the night sky became apparent for the first time. What had been mere fuzzy blobs as seen by the unaided eye now had form, and suddenly a whole new world of nebulae, galaxies and star clusters could be observed.

When those first telescopes were trained on the stars, an interesting discovery was made: that not all the stars we see as single points of light with our eyes are, in fact, alone. Some were revealed to be two stars or maybe even more. Double stars and multiple star systems were discovered. As the number of double stars being found grew, it became necessary to divide the category up further, in order to clarify exactly what sort of double star it was.

To understand the first category, optical doubles, imagine the true 3D nature of space with stars sprinkled all over the place. From our viewpoint, one star may appear very close to another star, but this is only because the two stars

happen to lie in the same direction from us in space; these stars are not linked in any way. One of them could be much farther away from us than the other, but stargazing-wise, we have no way of knowing, because everything in the night sky looks the same distance away.

Interacting stars

Then there are the double stars that are linked by gravity. If you see one of these you're looking at a binary star. It's no coincidence that the stars of a double appear to be in the same place: they are both the same distance from us, and they orbit around each other. It's estimated by some scientists that perhaps half of the stars in our Galaxy may be binaries, although binaries account for only five per cent of stars observed so far.

So how do you know which is which? Well, unless a magazine or star atlas tells you, there is no way of telling whether you're looking at an optical double or a binary. Only with the careful study of the movements in a double star can we gauge

whether the stars are gravitationally bound to each other or not.

If you're looking up at a binary star system, it's fascinating to know what could be happening with the stars themselves. This is because sometimes the stars in a binary system can interact – especially when one of the stars is more massive than the other. In this case, gas can be pulled off the smaller companion, which can lead to destructive stellar explosions called novae.

Of course, you won't see any of this going on when you look through a telescope, but double stars are still amazing targets to aim at. Some doubles show startling colour differences – you may see, for example, a shimmering yellow star next to a vivid blue one – while with other double stars, the two will be more or less the same brightness, yet sit startlingly close together. If you can spot our top five favourite doubles, which we've listed below, we have no doubt that you'll soon be hooked on these jewels of the night sky.

FIVE EASY TO SPLIT STELLAR PAIRINGS



1. ALBIREO

Constellation: Cygnus

RA 19h 30m 43s, dec. +27° 57' 34"
Albireo (Beta (β) Cygni) is a lovely golden and blue double that's a binary star system. The golden component is mag. +3.1, while the blue member is mag. +5.1. You'll need a scope to see the pair.



2. ALMACH

Constellation: Andromeda

RA 02h 03m 54s, dec. +42° 19' 47"
Almach (Gamma (γ) Andromedae) is the third brightest star in its constellation and is made up of a mag. +2.3 yellow star with a mag. +5.1 companion. To resolve them you'll need to use a telescope.



3. THE DOUBLE DOUBLE

Constellation: Lyra

RA 18h 44m 20s, dec. +39° 40' 12"
To the naked eye, Epsilon (ε) Lyrae's two yellow stars have a similar brightness of mag. +5.5. However, with a scope you'll see that each part in fact has its own binary companion.



4. MIZAR AND ALCOR

Constellation: Ursa Major

RA 13h 23m 55s, dec. +54° 55' 31"
Zeta (ζ) and 80 Ursae Majoris are an optical double. Being able to see the two white stars, mags. +2.2 and +4.0, with the naked eye was a traditional test of how good your eyesight was.



Albireo is a beautiful binary star with striking gold and blue components



5. THETA TAURI

Constellation: Taurus

RA 04h 28m 34s,
dec. +15° 57' 43"

This orange and white optical double in the Hyades is visible to the naked eye, at mag. +3.8 and +3.4 respectively. The dimmer star is actually slightly variable, changing from +3.35 to +3.42 over 1.82 hours.

TESTING YOUR SCOPE

You can use double stars to test your telescope's optics. How well you can split the stars depends on the quality of your optics, as well as the size of your telescope's aperture, or front lens.

If you have a good-quality small telescope, say four inches in diameter, you should be able to see doubles as close as 1.15 arcseconds if seeing conditions are perfect. Our top five doubles on the left should all be easily within your reach.

To split double stars closer than this, you need a larger telescope. To find

out the closest double stars a telescope will theoretically split, you just divide 4.6 by the diameter of the telescope's front lens in inches. It's only a theoretical figure, though, because if the atmosphere is fairly turbulent then you won't be able to see the components of a really close double star well.





Algol, the middle star in the row of three just below centre, is an eclipsing binary with a period of nearly three days

VARIABLE STARS

Not all stars shine steadily all of the time – some appear to alter in brightness regularly – and you can observe this from Earth

At first glance, or even after a prolonged stare, it can seem like the starlit night changes very little. Apart from the slow movement of the sky caused by Earth's rotation and the odd meteor, nothing much else appears to happen.

However, if you know when and where to look, even the seemingly fixed stars can take on a life of their own. After a little investigation, you'll see that the night sky is, in fact, constantly changing.

This is because of variable stars, stellar wonders that change in brightness over time. Some do so in just a few hours, while others take several years. The time it takes for a variable star to complete one cycle is known as its period.

Spice of life

Variables come in many forms, the main types being intrinsic and extrinsic variables. If you're looking for action,

then look out for an intrinsic variable. The changes happen within the star itself. It may pulsate in and out, for example, getting brighter and fainter as it goes.

One type of intrinsic is the long-period variable. These tend to be unstable older stars fighting internal battles with gravity and pressure, resulting in them growing and shrinking over long periods of time. They make good observing targets: some can be seen with the naked eye when they

are at their brightest, yet they can then dim so much only a pair of binoculars or a telescope will reveal them.

The action really starts to hot up with another group of intrinsic stars called cataclysmic – or explosive – variables, which pull gas off their close neighbours. The pile-up of new gas leads to nuclear explosions, called novae, which result in a dramatic increase in brightness. The dying explosions of old stars, called supernovae, are also part of this group.

Add in the eruptive variables, which include stars whose surfaces flare up from time to time, and it's clear how active the intrinsic type really is.

Outside influence

Meanwhile, extrinsic variables owe their changeable nature to an external element. Take an eclipsing binary, for example – this is where the orbits of two close stars are such that, from our perspective, one appears to move in front of the other as they go around. The amount of light we see coming from the system changes whenever one star eclipses the other.

Then there are rotating variables. These stars spin so fast that their light output is actually affected: if we could see them they would have a squashed appearance. The variability of these stars is controlled by a light-bending phenomenon called gravitational microlensing.

Watching out for the fluctuating light of variable stars is a perfect project for amateur astronomers. With a relatively inexpensive telescope, you can add to the knowledge bank professional astronomers may use to study how the Universe works. There are so many variable stars that they would never be able to look at them all without your help.

MEASURING STICKS FOR THE UNIVERSE

Cepheids are intrinsic variable stars that are useful to astronomers because they have a very regular period of light change. Some change just once day, while others take a month or more to complete their cycle. The period is linked precisely with the true brightness of the star – so a Cepheid with a five-day period near to us is the same true brightness as a five-day Cepheid in a distant galaxy. As we know exactly how light diminishes with distance, we can work out how much farther away the distant Cepheid is, using it to help measure distances in space.

FIVE FAMOUS VARIABLES



1. DELTA CEPHEI

RA 22h 29m 10s,
dec. +58° 24' 54"
Type: Pulsating variable; it's also the prototype of all Cepheid variables
Range: Mag. +3.9 down to mag. +5.0
Period: 5 days 9 hours
Best time to see: Autumn
Constellation: Cepheus
Equipment: Naked eye



2. MIRA

RA 02h 19m 20s,
dec. -02° 58' 39"
Type: Long-period red giant; the first of its type discovered
Range: Mag. +2.0 down to mag. +10.1
Period: 332 days
Best time to see: Autumn
Constellation: Cetus
Equipment: Binoculars



3. RASALGETHI

RA 17h 14m 38s,
dec. +14° 23' 25"
Type: Massive semi-regular old red supergiant
Range: Mag. +2.8 down to mag. +4.0
Period: About 3 months
Best time to see: Summer
Constellation: Hercules
Equipment: Naked eye



4. ALGOL

RA 03h 08m 10s,
dec. +40° 57' 20"
Type: Eclipsing binary
Range: Mag. +1.6 down to mag. +3.0
Period: 2 days 21 hours; brightens over 10 hours
Best time to see: Autumn
Constellation: Perseus
Equipment: Naked eye



5. RS OPHIUCHI

RA 17h 50m 13s,
dec. -06° 42' 28"
Type: Recurrent nova
Range: Mag. +5.0 down to mag. +12.5
Period: Around 20 years
Best time to see: Summer
Constellation: Ophiuchus
Equipment: Telescope; naked eye when bright



Not all clusters exist in isolation; the Trapezium Cluster is embedded in the Orion Nebula

STAR CLUSTERS

Groups of stars against the blackness of space, clusters make great observational targets for the amateur astronomer

When you gaze up at the night sky, it looks like a lot of stars are on their own. But a solitary-looking star may be a member of a vast group that's travelling through space as a unit. If we wind the clock back millions of years, we may find these stars forming in the same vast cloud of dust and gas.

Known as open clusters, these families of anywhere from a few dozen to a few thousand stars are created in the dusty spiral arms of our Galaxy. They travel together through space, but gentle tidal forces eventually cause the stars to move

apart until they begin to merge into the general starry background.

There are many fine examples of newer and older clusters out there, perfect for looking at with binoculars. As a rule of thumb, you can pretty much assume that the younger the open cluster, the more compact it appears, since the stars haven't had much time to drift apart.

There is another variety of star cluster out there: the globular cluster. These are much bigger than the open sort, consisting of hundreds of thousands or millions of generally reddish, older

stars. Whereas open clusters are found and made within the plane of our Galaxy, globular clusters form a halo around it and their creation is much less well understood.

In terms of observing, this all means that the majority of open clusters are found in or close to that misty river of stars stretching across the sky, the Milky Way, while globular clusters are seen all over the sky. When looking at them with the naked eye you'll see only fuzzy patches, but a pair of binoculars will reveal some truly spectacular gems.

OUTSTANDING OPEN CLUSTERS



M45

Constellation: Taurus

RA 03h 45m 48s, dec. +24° 22' 00"

The Pleiades, or Seven Sisters, is one of the most splendid clusters in the night sky. With the naked eye, six stars of the cluster are easy to see, but counting up to 10 is possible. The cluster actually contains many hundreds of stars, and a decent pair of binoculars will be able to reveal many of them.



NGC 869 AND NGC 884

Constellation: Perseus

RA 02h 19m 00s, dec. +57° 09' 00"

This is the 'Sword Handle', a wondrous double cluster with two star clusters sitting side by side. They are both 0.5° in diameter and are easily visible to the unaided eye. Try sweeping the area with binoculars – the hundreds of stars, set against the backdrop of the Milky Way, make for a fine sight.



M7

Constellation: Scorpius

RA 17h 53m 54s, dec. -34° 49' 00"

Also known as the Ptolemy Cluster, this appears to be twice the size of the full Moon. To the eye, the 80 stars of the cluster appear as a bright clump in the Milky Way, but through binoculars the stars are resolved.



M35

Constellation: Gemini

RA 06h 08m 54s, dec. +24° 20' 00"

This cluster contains upwards of 200 stars and can just be seen with the unaided eye on good clear nights. Binoculars bring out the brightest 20 or so stars, while the rest form a diffuse oval wash behind.



M44

Constellation: Cancer

RA 08h 40m 06s, dec. +19° 59' 00"

Known as the Beehive Cluster, M44 contains hundreds of stars and can be seen as a misty patch with the naked eye. Binoculars are the best way to see M44: through them you'll see a dozen or so of its brightest stars.

GREAT GLOBULARS



M13

Constellation: Hercules

RA 16h 41m 42s, dec. +36° 28' 00"

Known as the Great Globular Cluster, this is the best of its kind in the northern hemisphere. From a dark site, M13 can just be seen with the unaided eye, but its bright, round form is a stunning sight through a pair of binoculars.



M5

Constellation: Serpens

RA 15h 18m 36s, dec. +02° 05' 00"

This is thought to be one of the oldest of all globular clusters. It is easily found in binoculars and has a slightly oval-shaped appearance. What you'll see is a fuzzy blob, hinting at the vast number of stars it contains.



M22

Constellation: Sagittarius

RA 18h 36m 24s, dec. -23° 54' 00"

One of the brightest globular clusters, M22 is easily visible with the unaided eye, and a great sight through binoculars. It's larger than M13, which is impressive, but its place in the Milky Way's river of stars makes this a real jewel in the crown.



M3

Constellation: Canes Venatici

RA 13h 42m 12s, dec. +28° 23' 00"

This is another stunning globular cluster. It can just be seen with the unaided eye, but binoculars will reveal its bright, round shape that holds around 500,000 stars. 274 of these are known to be variable, the largest number in any known globular cluster.



M15

Constellation: Pegasus

RA 21h 30m 00s, dec. +12° 10' 00"

Looking like a slightly more compact M13, this densely packed object is an ideal target for binoculars. It appears as a round smudge with quite a compact central region, giving this distant star cluster a real sense of depth.

NGC 3372, the southern sky's Carina Nebula, is four times larger than M42

NEBULAE

Whether they glow on their own or reflect the light of nearby stars, these clouds of gas and dust are popular targets

Nebulae are clouds of gas and dust that are scattered throughout the Milky Way, mainly in the galactic disc, and it's here that stars are born. The word is Latin for 'little mists' – long ago, we considered all deep-sky objects to be nebulae, galaxies included, because they were faint fuzzy patches in the otherwise black night. These days, not only can we differentiate between nebulae and galaxies, but we know that several types of nebula exist.

The most famous nebula of them all, M42 in Orion, is what's known as an emission nebula. Nebulae of this type have a glow of their own, a result of stars within or nearby ionising the gas cloud. On the other hand reflection nebulae, like the one around the Pleiades star cluster in Taurus, are only visible because there are some stars nearby that light up the gas and dust, just as the Sun lights up a cloud in an otherwise blue sky.

Dark nebulae, such as the Horsehead Nebula, don't glow at all, as they are so dense they absorb light. They are only visible because they are in front of a

bright nebula or field of stars. We effectively see a silhouette of the cloud, but no detail in it.

You might think that planetary nebulae, such as the Ring Nebula in Lyra, have something to do with planets, but you'd be wrong. They get their name because, through a telescope, many have the appearance of a faint, small, fuzzy disc and can look a lot like a planet. These nebulae are formed during the death of a star of similar mass to the Sun. As it grows unstable, the star puffs off its gaseous atmosphere to form clouds around it. Stars larger than the Sun end their days explosively in a supernova, leaving a spectacular remnant in their wake.

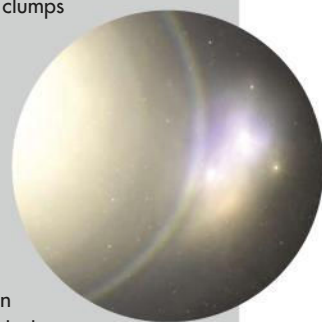
Astro images will reveal that many nebulae have vivid colours – typically red in emission nebulae from ionised hydrogen atoms and hues of blue stars in reflection nebulae – but the view through binoculars or a telescope will be quite different. Visually, nebulae appear in shades of grey.

STELLAR NURSERIES

Nebulae are where stars are created. One idea of how it all starts is that a shockwave from a nearby supernova explosion compresses the cloud. Once the density of the gas passes a critical point, gravity takes over.

Gravity causes clumps of the nebula to pull together. The pressure at the centre of the clumps builds and the temperature rises dramatically. If there is enough gas to fuel the process, the region can become a protostar.

If the temperature in the clump reaches 10 million degrees Celsius, the nuclear furnace that powers stars ignites. Over tens of millions of years it settles into normal life and joins what's called the main sequence, like our own Sun.



AMAZING NEBULAE



THE ORION NEBULA, M42

Constellation: Orion

RA 05h 35m 17s, dec. -05° 23' 28"

M42 is the brightest nebula in the night sky and the only one that can be seen with the naked eye. With a casual glance below the three belt stars of Orion in a dark, light-pollution free sky, you'll see this emission nebula as a small misty smudge. A pair of binoculars will begin to reveal its curving shape. With a small telescope, you will start to see some structure. In the heart of the Orion Nebula are four stars. These are part of the Trapezium open cluster, named because of the shape the four stars form. It's the radiation from these stars that is energising the entire nebula and causing it to glow.



THE CRAB NEBULA, M1

Constellation: Taurus

RA 05h 34m 32s, dec. +22° 00' 52"

M1 is what remains of a cataclysmic stellar explosion witnessed from Earth in 1054. It can be spotted with a small telescope, but it's best seen through a really large aperture instrument – only then does its texture start to emerge.



THE LAGOON NEBULA, M8

Constellation: Sagittarius

RA 18h 03m 37s, dec. -24° 23' 12"

This easily noticeable emission nebula can be seen as a brighter patch with the beginnings of a core in 10x50 binoculars, even sitting where it does within the constellation of Sagittarius – a busy and star-rich area of the Milky Way.



THE NORTH AMERICA NEBULA, NGC 7000

Constellation: Cygnus

RA 20h 59m 17s, dec. +44° 31' 44"

It takes a bit of practice to see emission nebula NGC 7000, also known as the North America Nebula, as it's such a large object. It's close to the bright star Deneb in Cygnus, and the surrounding area contains many targets for binoculars.



THE OMEGA NEBULA, M17

Constellation: Sagittarius

RA 18h 20m 26s, dec. -16° 10' 36"

This glowing emission nebula and star-forming region sits among the star fields of Sagittarius. It has a curved shape that can be likened to the Greek capital letter omega, Ω, hence its name, though it is sometimes called the Swan Nebula.



THE DUMBBELL NEBULA, M27

Constellation: Vulpecula

RA 19h 59m 36s, dec. +22° 43' 16"

This fascinating and relatively bright planetary nebula appears as a misty oval in small telescope, with the Milky Way providing a marvellous backdrop. The 'dumbbell' shape only becomes apparent through large instruments.



THE HORSEHEAD NEBULA, BARNARD 33

Constellation: Orion

RA 5h 40m 59s, dec. -02° 27' 30"

The Horsehead Nebula, to the south of Orion's Belt in the Orion Molecular Cloud Complex, is a dark nebula that appears silhouetted against a brighter background of nebulosity. You will need a large aperture instrument and dark skies to make it out.

GALAXIES

These shining arks of stars come in all shapes and sizes, many the result of cosmic collisions

Galaxies are concentrations of millions or billions of stars, gravitationally bound together along with gas clouds and pockets of dust. There are probably over 100 billion of them in the Universe. Some of the largest nearby galaxies appear in the night sky as faint smudges of light, but it was only in the early 20th century that astronomer Edwin Hubble proved that they actually exist well beyond the Milky Way. Before then, they were thought to be spiral-shaped nebulae on the outskirts of our own Galaxy.

Hubble also established that galaxies vary in shape and size. Two-thirds have distinctive spiral patterns, while the rest range from neat ellipticals to irregular blobs. They can be dwarves containing millions of stars or giants harbouring trillions. Astronomers are still piecing together why this is the case, but collisions and mergers seem to be important in determining how a galaxy evolves. Central black holes also seem to govern how gas is consumed and when stars are formed within these cosmic conurbations.

Hidden mass

Galaxies are much more massive than they look. Around 90 per cent of their mass is not in luminous stars and gas, but in unseen 'dark matter'. It's arranged in a spherical halo, which governs the motions of the stars within. This invisible cocoon explains why the outskirts of spiral galaxies spin faster than if they were influenced by the quantity of stars and gas alone. Dark matter also governs how galaxies clump together under gravity to form filaments and clusters. Yet dark matter remains an enigma, and astronomers are still trying to discern what it is. It must be exotic as it does not absorb or emit light.

Spiral galaxies such as the Milky Way are named for the arcs of bright stars that corkscrew into their centres. The spiral is a density wave embedded in a flattened disc of stars and gas that is arranged around a central bulge. Bright stars form where gas clouds are compressed. The



Bode's Galaxy is the largest of 34 in the M81 Group; it is around 11.7 million lightyears away

disc is full of young stars and gas, and tends to be blue; the bulge appears redder. Discs form when a cloud of gas collapses under its own gravity, spinning faster as it shrinks vertically. Spirals are common across space, apart from in the centres of galaxy clusters, where discs are easily destroyed by collisions.

Shaped like rugby balls, elliptical galaxies are much like the bulges of spirals, but lack any disc. They contain little gas, and few stars are being formed within them. Old, red stars are the norm, travelling on inclined elliptical orbits. Groups of elliptical galaxies are often found in the centres of galaxy clusters.

Lenticular galaxies are lens shaped, their classification falling between spirals

and ellipticals. Many are similar to spiral galaxies, containing a relatively small disc and large bulge, but lacking the spiral arms. These may be faded spirals, in which star formation has ceased. Others are likely to be the result of galaxy collisions, which could have ripped off part of a larger disc, or shut down star formation after a vigorous burst.

Irregular galaxies do not fall into any of the other main classification categories – they have no distinctive shape. This may be because they have been distorted in a collision or they may have formed that way. Some dwarf galaxies condensed in a haphazard manner from gas clouds and haven't settled into an ordered state.

GLIMPSES GALAXIES



THE ANDROMEDA GALAXY, M31

Constellation: Andromeda

RA 00h 42m 42s, dec. +41° 16' 00"

The magnificent Andromeda Galaxy is the nearest large galaxy to the Milky Way, and it is possible to see it with the naked eye. Under dark, Moon-free skies, you should be able to find this spiral galaxy as a faint misty patch a short distance from the band of the Milky Way without optical aids. Using binoculars, you'll find it with little or no difficulty. It will be oval in appearance – although you won't be able to make out any of the individual stars within it. Through a 6-inch telescope the galaxy appears as a larger, elongated oval shape with a core that shows up as a slightly brighter area.



THE WHIRLPOOL GALAXY, M51

Constellation: Canes Venatici

RA 13h 30m 00s, dec. +47° 16' 00"

The Whirlpool Galaxy is a magnificent face-on spiral located in Canes Venatici. It can be found not far from mag. +1.9 Alkaid (Eta (η) Ursae Majoris). You'll need a large telescope to see its spiral arms clearly.



THE TRIANGULUM GALAXY, M33

Constellation: Triangulum

RA 01h 33m 54s, dec. +30° 39' 00"

M33 can just be seen with the naked eye under pristine dark skies, but light pollution means binoculars at least. It sits between mag. +2.2 Hamal (Alpha (α) Arietis) and mag. +2.1 Mirach (Beta (β) Andromedae).



THE SOMBRERO GALAXY, M104

Constellation: Virgo

RA 12h 40m 00s, dec. -11° 37' 23"

Located just within Virgo, this spiral galaxy is easy to see in any scope. A 6-inch instrument shows an elongated glow, but its defining characteristic is a dark dust lane that cuts across the south of the central halo.



M81 AND M82

Constellation: Ursa Major

RA 09h 55m 33s, dec. +69° 03' 55"

These galaxies in Ursa Major, M81 or Bode's Galaxy (co-ordinates above) and M82 the Cigar Galaxy, are close to each other in the sky, so we're treating them as one sight here. With a small telescope and a low magnification eyepiece, you'll be able to see them in the same field of view.



THE LEO TRIPLET

Constellation: Leo

RA 11h 18m 55s, dec. +13° 05' 32"

The Leo Triplet is comprised of the spiral galaxies M65 (co-ordinates above), M66 and NGC 3628, and lies about halfway between mag. +3.3 Chertan (Theta (θ) Leonis) and mag. +6.6 Iota (ι) Leonis. Larger telescopes will show them clearly. Another group, M95 and M96, is nearby.



THE PINWHEEL GALAXY M101

Constellation: Ursa Major

RA 14h 03m 12s, dec. +54° 20' 57"

This face-on spiral galaxy is comparable in size to the Milky Way, and while it can be spotted in binoculars its magnitude of +7.9 means you'll need dark skies and a 6-inch telescope to see its spiral arms.

ASTRONOMY MYTHS DEBUNKED

Eight of the biggest astronomical myths, collected and comprehensively busted to help you become an expert in no time at all

THE MOON CAN'T BE SEEN IN THE DAYTIME

There's a common conception that just as the Sun can only be seen in daylight hours, the Moon only comes out at night. But Earth's rotation means that the Moon must be above the horizon for 12 hours out of every 24, regardless of the length of the night. As such, the Moon is often somewhere in the daylit sky. Whether we see it is down to two things – its altitude in the sky and its phase.



POLARIS IS THE BRIGHTEST STAR IN THE SKY

Polaris is certainly among the most famous, being star closest to the north celestial pole, but this usefulness does not make it the brightest in the sky. Spend an evening outside and it will become obvious that this honour falls to Sirius, in the constellation of Canis Major.

STARS TWINKLE

'Twinkle, twinkle, little star' has a lot to answer for. Stars often appear to flicker in the night sky, but this has nothing to do with the star and everything to do with our turbulent atmosphere. Once it reaches Earth, starlight is reflected, bent and contorted by this turbulence, until it reaches your eye. Viewed from space, stars would not twinkle at all.



EARTH'S DISTANCE FROM THE SUN CAUSES THE SEASONS

Not so – Earth is actually closest to the Sun during the northern hemisphere's winter. The real reason is due to Earth's 23.5° axial tilt, which means each hemisphere gets varying durations of sunlight over the year.

POLARIS HAS ALWAYS BEEN THE POLE STAR

Polaris's position next to the north celestial pole is a temporary one, a result of Earth wobbling on its axis as it spins. The change is about 1° every 72 years, with a full cycle taking around 26,000 years. In 3,000 BC the pole star was Thuban in Draco, but in 2,000 years time it will be Errai in Cepheus.

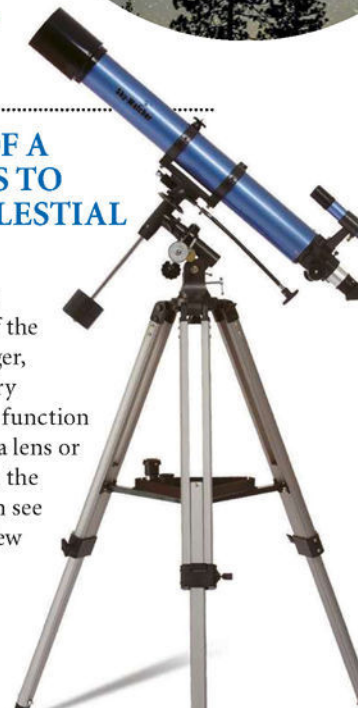
SHOOTING STARS ARE REALLY STARS

If you have ever wished upon a star, you may be shocked to learn it wasn't a star at all. What you saw was the bright flare of piece of debris, likely to be no bigger than a grain of sand, burning up in our atmosphere. They are properly known as meteors. If a fragment makes it to Earth's surface, it is called a meteorite.



THE POINT OF A TELESCOPE IS TO MAGNIFY CELESTIAL OBJECTS

While telescopes can make the denizens of the night sky appear bigger, this isn't their primary purpose. Their main function is gather light, using a lens or mirror depending on the design, so that we can see objects too dim to view with the naked eye.



THE MOON HAS A DARK SIDE

The phrase 'dark side of the Moon' is often and erroneously used to refer to the Moon's far side, which means something subtly different. The far side is the hemisphere of the Moon permanently turned away from Earth, but calling it the dark side implies it is never sees any sunlight – which is not the case. The lunar far side goes through the same cycle of phases as we see on the near side from Earth, with the only period it can technically be called the dark side being the time of full Moon.



OPTICS OF DISTINCTION



OSTARA ELINOR

The award winning Elinor range has it all with an ultra wide field of view providing a high resolution, comfortable and an incredibly stable image. Features include large eyepiece lenses for very comfortable, long eye relief viewing. The body has tough rubber armour and is waterproof.

All surfaces are fully multicoated further enhancing brightness and clarity. Optical Hardware's broad lightband transmission ensures incredibly accurate colour rendition.



30 YEAR
GUARANTEE

Available in a choice of magnifications
7x50 | 8x45 | 10x50 | 12x50

**OPTICAL
HARDWARE**

Ostara binoculars are manufactured and distributed by Optical Hardware Ltd.
For more information and to find your nearest stockists, please visit www.opticalhardware.co.uk/stockists
All offers are subject to availability, prices and specifications are subject to change without notice. E&O.E. Your statutory rights are not affected.



CELESTRON®

TECHNOLOGICALLY SUPERIOR

NEW TELESCOPES FROM CELESTRON

INSPIRE™

Get inspired by Celestron! The ultimate telescope for the novice to intermediate astronomer, the Inspire range is loaded with exciting new features. The innovative lens cap converts to a universal smartphone adapter for imaging with your phone. The mount has a built in red flashlight to illuminate the accessory tray. Conveniently, the flashlight is also easily removable for use independently.

Available apertures: 70mm, 80mm and 100mm



Inspire 100AZ Refractor

ASTRO FI™

Celestron is not only changing the way we experience astronomy, but we're also changing the way you interact with the night sky. The Astro Fi range can be controlled with your smart phone or tablet using the free Celestron SkyPortal app! It's never been more fun to explore the universe!

Available apertures: 90mm, 102mm and 130mm



Astro Fi 130mm Newtonian

CELESTRON
SkyPORTAL



iPAD and iPHONE SHOWN
NOT INCLUDED.

Available from specialist astronomy retailers and selected other dealers nationwide.

Celestron is distributed in the UK & Ireland by David Hinds Limited. Trade enquiries welcomed.

www.celestron.uk.com

@David_Hinds_Ltd

Celestron®, Inspire™ and Astro Fi™ are registered trademarks or trademarks of Celestron Acquisition, LLC in the United States and in dozens of other countries around the world. All rights reserved. David Hinds Ltd is an authorised distributor and reseller of Celestron products. The iPhone®, iPad® and App Store are registered trademarks of Apple Inc. Google Play is a registered trademark of Google Inc.